

Utility Solid Waste Activities Group

c/o Edison Electric Institute
701 Pennsylvania Avenue, NW
Washington, DC 20004-2696
202-508-5645
www.uswag.org

USWAG

June 22, 2005

Mr. Mark Friedrichs
PI-40
Office of Policy and International Affairs
U.S. Department of Energy
Room 1E190
1000 Independence Avenue, S.W.
Washington, D.C. 20585

By email: 1605bguidelines.comments@hq.doe.gov

Re: 10 CFR Part 300 Revised General Guidelines and draft Technical Guidelines for the \$1605(b) Voluntary Reporting of Greenhouse Gases Program. 70 Fed. Reg. 15164-15192 (March 24, 2005)

Dear Mr. Friedrichs:

On behalf of the Utility Solid Waste Activities Group (USWAG) and a subset of USWAG members and other utilities referred to as "C2P2 Funders"¹, I respectfully submit these comments on the Department of Energy's Revised General Guidelines and draft Technical Guidelines for the \$1605(b) Voluntary Reporting of Greenhouse Gases Program. 70 Fed. Reg. 15164-15192 (March 24, 2005).

Sincerely,



Jim Roewer
Executive Director

¹ C2P2 Funders are Alliant Energy, Ameren Corporation, American Electric Power, Cinergy, Constellation Energy Group, Consumers Energy, First Energy, AES-IPALCO, LG&E Energy Corporation, Mirant Corporation, Montana-Dakota Utilities Company, Progress Energy, Public Service New Hampshire, Public Service Enterprise Group, Reliant Energy, Southern Company, Tri-State Generation and Transmission, TVA, and Xcel Energy.

**COMMENTS OF THE
UTILITY SOLID WASTE ACTIVITIES GROUP
AND
C2P2 FUNDERS**

on the

**U.S. DEPARTMENT OF ENERGY
REVISED GENERAL GUIDELINES AND DRAFT TECHNICAL GUIDELINES
FOR EPACT SECTION §1605(b) VOLUNTARY GHG REPORTING**

**FEDERAL REGISTER
VOL. 70, NO. 56
PAGES: 15164 – 15192**

**U.S. DEPARTMENT OF ENERGY
10 CFR PART 300
RIN 1901 – AB11**

**Submitted by:
James Roewer
Executive Director
Utility Solid Waste Activities Group
701 Pennsylvania Ave., N.W.
Washington, D.C. 20004
202/508-5645
jim.roewer@uswag.org**

June 22, 2005

Introduction

The Utility Solid Waste Activities Group (USWAG), along with a subset of USWAG members and other utilities referred to as “C2P2 Funders”² (collectively, “USWAG”) respectfully submit these comments on the Department of Energy’s revised general guidelines for the Voluntary Reporting of Greenhouse Gases Program. 68 Fed. Reg. 68204 (December 5, 2003).

DOE’s guidelines, as proposed, would not allow for registration of GHG reductions resulting from coal ash reuse. As described, coal ash reuse is but one of several types of actions which have previously been reported to DOE under the §1605(b) program that would not qualify for registration under the revised guidelines. Generally, those actions which could no longer qualify either achieved their emission reductions by activities other than energy supply, and/or posed measurement problems that could not be credibly and transparently surmounted.

In both the Federal Register notice and in comments made at the April 26-27 Public Workshop, DOE sought comment on the practicality of reporting such actions (either directly or as offsets), and suggestions on estimation methods that would mitigate the constraints described above. DOE noted that “In particular, DOE is open to future consideration of practical methods, consistent with the structure and objectives of the revised guidelines, to enable manufacturers of more energy efficient products to register the emission reductions resulting from the use of these products.” (F.R.15168)

USWAG agrees with DOE’s general logic, specifically with the overarching goal that avoided emissions need to meet a high level of measurement precision, transparency, and confidence before allowing them as registered reductions. To allow a lesser standard would risk undermining the broader goal of high-quality reporting for registered reductions, and confidence in the overall §1605(b) program.

To that end, USWAG and its industry and government partners have been working for nearly three years to improve the quality of reporting on CCP use and the procedures for estimating the associated GHG impacts. We now believe that we have such a reporting system developed, and that this can ably serve as a basis for §1605(b) reporting. With these comments, including the attached paper, USWAG is pleased to present this body of work for DOE’s consideration.

USWAG and the C2P2 Initiative

USWAG is responsible for addressing solid and hazardous waste issues on behalf of the utility industry. USWAG was formed in 1978, and is an informal consortium of approximately 80 utility operating companies, the Edison Electric Institute (EEI), the National Rural Electric Cooperative Association (NRECA), the American Public Power Association (APPA). EEI is the principal national association of investor-owned electric power and light companies. NRECA is the national association of rural electric cooperatives. APPA is the national association of publicly owned electric utilities. Together, USWAG member companies and trade associations represent more than 85% of the total electric generating capacity of the U.S. and service more than 95% of the nation's consumers of electricity.

USWAG's Mission is to address the regulation of utility wastes, byproducts and materials in a manner that protects human health and the environment and is consistent with the business needs of its members.

² C2P2 Funders are Alliant Energy, Ameren Corporation, American Electric Power, Cinergy, Constellation Energy Group, Consumers Energy, First Energy, AES-IPALCO, LG&E Energy Corporation, Mirant Corporation, Montana-Dakota Utilities Company, Progress Energy, Public Service New Hampshire, Public Service Enterprise Group, Reliant Energy, Southern Company, Tri-State Generation and Transmission, TVA, and Xcel Energy.

The Coal Combustion Products Partnership (C2P2) is one of the new actions established under the Power Partners initiative. C2P2 aims to increase the utilization of coal combustion products (CCPs) and thereby reduce CO₂ emissions to support President Bush's approach to addressing greenhouse gases.

USWAG, as the key representative of utilities, is working in partnership with the U.S. Environmental Protection Agency, the American Coal Ash Association (ACAA) and other government and private sector organizations to establish a series of coordinated efforts aimed at diverting coal combustion products (CCPs) from land disposal and reducing greenhouse gas emissions by increasing beneficial use of CCPs. The C2P2 project includes pilot program components targeting generators, manufacturers, and users of CCPs or products containing CCPs. USWAG's role in the Coal Combustion Products Partnership was recognized by EPA in its 2002 WasteWise Ceremony.

Growing Use of CCPs

Being comprised of both organic and inorganic materials, the combustion of coal creates large quantities of fly ash, bottom ash, boiler slag and flue gas desulfurization (FGD) material. The ash content of coal produced in the U.S. averages nearly nine percent, and the additional materials used in FGD processes are also substantial. Collectively, it is estimated that 121.7 million tons of these coal combustion products (CCPs) were produced in the U.S. in 2003, according to the annual surveys conducted by the American Coal Ash Association (ACAA).

For many years, particularly early in the electric power industry's history, CCPs were often looked upon as waste by-products needing disposal. In recent years, there has been growing awareness that productive use of CCPs provides many environmental and financial benefits. Utilization helps reduce greenhouse gas emissions (associated with the production of the materials now avoided), creates revenue for utilities, and reduces the need for land for disposal and, in turn, corresponding disposal costs. Further, these factors reduce the cost of electricity to the public, commerce and industry, which leads to greater economic growth. Finally, utilization reduces the volume of solid waste disposed and the volume of natural materials needed to be mined or otherwise obtained for construction purposes. In this regard, utilization of coal by-products has a strong environmental benefit.

CCPs are the fourth largest volume mineral resource produced in the United States. According to the ACAA, about 46.4 million tons of CCPs found beneficial use in 2003. This represents a substantial 44 percent increase over 2000 levels; it is thought that this increase is due both to improved survey reporting and to higher rates of CCP use. Over one-fourth of this usage was identified as "concrete, concrete products, and grout," and the rest was found among a number of other end-uses.

Each year, the ACAA sends out survey forms to collect data of types and quantities of CCPs used in a variety of end-use applications. We analyzed the results of the ACAA surveys for the calendar years 2000 through 2003. Beginning with the 2002 data year, the ACAA survey form was modified, adding some categories and making other refinements so as to better capture the growing volume and variety of CCP uses, and to more closely parallel data gathered by producers for Toxic Inventory Release (TRI) reporting. The ACAA survey in 2002 also added additional detail regarding the reporting of fluidized-bed combustor (FBC) ash, which in previous years it had probably been grouped in with fly ash tonnages. Further, beginning in 2002, FGD materials, which had previously been undifferentiated by type, were reported in four categories – FGD Gypsum, FGD Material Wet Scrubbers, FGD Material Dry Scrubbers, and FGD Other.

These efforts by the ACAA, both the steps taken to strengthen and define the CCP end-use categories and the efforts to increase survey response, have steadily improved the completeness and quality of the survey data. As an example, a summary of the 2003 survey is presented in Figure 1. As can be seen in the summary table, all of the CCP use has been identified by the type of CCP (fly ash, bottom ash, etc.), and

FIGURE 1

2003 COAL COMBUSTION PRODUCT (CCP) PRODUCTION AND USE

Usage, by Type of CCP (short tons)

<u>CCP End-use Market</u>	<u>Fly Ash</u>	<u>Bottom Ash</u>	<u>Boiler Slag</u>	<u>FGD Material</u>	<u>FBC Ash</u>	<u>2003 Total CCP Usage</u>
Concrete/Concrete Products/Grout	12,265,169	298,181	15,907	99,877	0	12,679,134
Cement/Raw Feed for Clinker	3,024,930	493,765	15,766	422,512	0	3,956,973
Flowable Fill	136,618	20,327	0	9,184	0	166,129
Structural Fills/Embankments	5,496,948	2,443,206	11,074	236,241	0	8,187,469
Road Base/Sub-base/Pavement	493,487	1,138,101	29,800	0	0	1,661,388
Soil Modification/Stabilization	515,552	67,998	0	818	188,708	773,076
Mineral Filler in Asphalt	52,608	0	31,402	0	0	84,010
Snow and Ice Control	1,928	683,556	102,700	0	0	788,184
Blasting Grit/Roofing Granules	0	42,604	1,455,140	0	0	1,497,744
Mining Applications	683,925	1,184,927	59,800	390,331	11,049	2,330,032
Wallboard	0	0	0	7,780,906	0	7,780,906
Waste Stabilization/Solidification	3,919,898	30,508	0	0	49,217	3,999,623
Agriculture	12,140	3,534	0	34,813	0	50,487
Aggregate	137,171	512,769	31,600	6,299	0	687,839
Miscellaneous/Other	396,150	1,327,797	2,815	0	14,649	1,741,411
Total Use	27,136,524	8,247,273	1,756,004	8,980,981	263,623	46,384,405

Source: American Coal Ash Association, 2003 Coal Combustion Product (CCP) Production and Use Survey, [http://www.acaa-usa.org/PDF/2003_CCP_Survey\(10-1-04\).pdf](http://www.acaa-usa.org/PDF/2003_CCP_Survey(10-1-04).pdf).

over 95 percent according to the end-use markets. This is a high level of certainty, and leads us to conclude that a reporting framework is in place and is working well to produce end-use information of high quality.

GHG Benefits of CCP Use

It is well known that use of coal combustion products (CCPs) to displace portland cement avoids substantial CO₂ emissions, both from the energy savings and from the limestone calcination avoided. However, as annual CCP surveys conducted by the American Coal Ash Association (ACAA) show, there are many other categories of CCP use, and many of these other uses also avoid the energy consumption and GHG emissions associated with production and use of other virgin materials. Although the CO₂ tonnage savings from these other uses are often much less than those from cement displacement, they are collectively significant.

To promote the goals of the C2P2 program, we wanted to be able to quantify the GHG benefits of *all* CCP uses, in order to enable CCP sellers and users to identify the climate-related benefits of their activities. To that end, we undertook research to develop a methodology for estimating the GHG savings that arise from use of coal combustion products in a variety of end-use applications. Our methodology seeks to conform to the ACAA Survey categories, so as to ensure consistency with industry practice and to facilitate estimates of CO₂ savings as future year data are collected. In this effort, we were assisted by the staff of the American Coal Ash Association (ACAA) and several of their member companies. The full details of this research are described in the paper accompanying these comments: *Estimating GHG Savings from Use of Coal Combustion Products: Methodology and Results for 2000-2003*, by James Roewer (USWAG) and Daniel E. Klein (Twenty-First Strategies), dated June 2005, and also included here as Attachment A to these comments.

In developing estimates of energy and GHG emissions saved by using CCPs, we formulated and implemented a five-step methodology:

1. ***Assumed “But For” Materials.*** For each of the CCP end-uses in the ACAA Survey, we first identify the “but for” case; that is, what other materials would have had more demand and consumption but for the use of the CCPs. For example, in the category “concrete, concrete products, and grout,” if the flyash portion of the CCPs had not been used, the “but for” case would have been greater use of portland cement, along with its associated energy use and CO₂ emissions. Since CCPs have a variety of uses, for some CCP uses there may be more than one “but for” material displaced. Also, for some end-uses the CCPs displaced the “but for” material at a ratio either more or less than one ton of CCPs per ton of displaced material.
2. ***Developing Per-Ton Energy Estimates for the “But For” Products.*** Next, we develop per-ton energy estimates for the various “but for” products (or their proxies) that CCPs have displaced. We identify the energy use by type of fuel for each product, and then convert the physical units of energy into Btu using each fuel’s average energy content.
3. ***Calculate the Per-Ton CO₂ Emissions for the “But For” Products.*** Next, we estimate the CO₂ emissions associated with the production of the various “but for” products. These avoided CO₂ emissions are the sum of the emissions from the fuels consumed, plus any CO₂ emissions released in the calcination processes.
4. ***Calculate the Per-Ton Energy and CO₂ Factors for each CCP Type and End-Use.*** For each CCP type and end-use, we now have developed estimates of which “but for” products were displaced and in what proportion, and the associated energy and CO₂ emissions for each. These can now be combined into a set of per-ton factors to be applied to the categories in the ACAA annual surveys of CCP use.
5. ***Calculate the 2000-2003 CO₂ Savings from CCP Use.*** Lastly, for each of the major categories of CCP use, multiply the tonnage of CCP use by the replacement ratio (if any), and multiply by the per-ton estimates of CO₂ savings (both from energy savings and avoided calcination, if any).

We applied this methodology to ACAA’s Annual Surveys for the four-year period 2000-2003 to estimate total GHG savings. In 2003, for example, the analysis found that CCP usage had grown to 46.4 million tons, leading to an estimated avoidance of 14.7 million tons of CO₂. Of this, the amount used in “concrete/concrete products/grout” comprised 12.7 million tons of CCPs and avoided about 11.4 million tons CO₂. The remaining CCP use categories collectively comprised 33.7 million tons of CCPs and avoided 3.2 million tons CO₂.

Developing a Protocol for §1605(b) Reporting of CCP Use

Section 300.8 of the revised General Guidelines provides guidance on five different calculation methods for emissions reductions. The fifth method is called the “action-specific” method, and refers to those actions or projects whose emission reductions cannot be quantified using any of the other approaches of emissions intensity, absolute emissions, avoided emission, or carbon storage.

Many of these specific actions do not easily allow reporters to develop an estimate of base-year emissions based on technologies and base-year activity levels. DOE has provided guidance in the draft Technical Guidelines for a few of these action-specific reductions, including coalmine degasification, landfill methane recovery, transmission and distribution improvements, and geologic sequestration. DOE specifically requested guidance of other specific actions for which guidance should be provided.

While DOE requested recommendations on other specific actions that could be included, it tentatively shut the door on some actions that might *not* be eligible for registration as action-specific reductions (*Federal Register*, page 15167). These actions include widely-embraced as frequently-reported

activities including utility-sponsored DSM programs, manufacturer improvement in the energy efficiency of products, employee commuting reduction, coal ash reuse, halogenated substance substitution, and materials recycling/source reductions.

DOE's tentative exclusion of these activities appears to rest upon one question of ownership and three questions of measurement credibility:

- For the ownership issue, DOE indicated that if the reporting entity enters into an agreement with the entity directly responsible for the reductions, then they could be reported as "offsets" under the revised guidelines. Absent such an agreement, the reduction would not qualify for registration.
- These actions often result in avoided emissions from activities other than energy supply, instead creating reductions by using less GHG-intensive materials in the manufactured products. Presumably, these reductions are harder to measure accurately than are energy-related emissions, where the CO₂ is a co-product emission with the amounts of CO₂ emitted being directly and immediately related to the activity's inputs, particularly fossil fuel consumption.
- These actions often result in reduced emissions from highly diffuse sources; the example presented in the Guidelines was that of public education related to energy conservation.
- For some of these actions, the location and resulting reductions is impossible to determine; the example presented in the Guidelines was that of retail sales of compact fluorescent bulbs.

In pointing out these concerns that collectively led it to tentatively decide to exclude these activities from registered reductions, DOE also invited commenters to suggest solutions that could allow reporting. As DOE stated (*Federal Register*, pages 15167-15168), "DOE seeks comment on the practicality of reporting these actions directly or as offsets, and suggestions on estimation methods that would mitigate the constraints identified above and allow reductions from a broader range of such actions to be reported. In particular, DOE is open to future consideration of practical methods, consistent with the structure and objectives of the revised guidelines, to enable manufacturers of more energy efficient products to register the emission reductions resulting from the use of these products."

This is a worthy goal, and we appreciate DOE's openness and willingness to consider new ideas and information. Accordingly, USWAG submits for DOE's consideration a general framework for gauging when a specific action can be reported. Then, we apply this framework to the case of CCPs to demonstrate the appropriateness of including coal ash reuse as a specific action that eligible for registering GHG reductions.

General Framework for Reporting Action-Specific GHG Reductions

As we noted above, DOE's tentative exclusion of some forms of specific actions appears to rest upon questions of ownership and/or measurement credibility. By inviting comment, DOE indicates that these are issues that can be overcome, rather than insurmountable obstacles.

This willingness to consider comments implicitly recognizes that accounting for GHG reductions can be a complex task for which we may not now know all of the answers. However, we also have the capacity to learn, and over time our methods can evolve into coverage that is more accurate, more credible, and more comprehensive. A similar "learn-by-doing" approach is exhibited in international projects, where the CDM Executive Board under the UNFCCC, where the Board has approved a list of baseline and monitoring methodologies for various CDM projects, but also has developed procedures wherein new methodologies can be proposed, review, and possibly accepted and approved for broader CDM project use. (see <http://cdm.unfccc.int/methodologies>)

We suggest that in deciding whether a new class of action-specific emissions reductions should qualify for registration, DOE should address the following issues:

1. Can “ownership” of the reductions be clearly established?
2. Is the GHG intensity of the product or activity at its source clearly and transparently quantifiable?
3. If the GHG reductions are dependent upon the distribution across end-use markets, is there credible information on sales to these various end-use markets?
4. In an end-use market, is there a credible methodology for calculating GHG reductions?
5. If the GHG reductions are dependent upon the usage pattern within end-use markets, is there credible information on the usage patterns of end-users?

If these issues can be satisfactorily resolved, then DOE is on solid footing to allow those forms of specific actions to qualify for registration. For the action-specific reductions already addressed in section 2.4.5 of the draft Technical Guidelines – coalmine degasification, landfill methane recovery, transmission and distribution improvements, and geologic sequestration – it appears that these issues have been satisfied.

Application of the General Framework to CCPs

Using these five questions, we now demonstrate how coal ash reuse (or, more broadly, CCP use) meets the ownership and measurement concerns raised by DOE, and accordingly should be considered as an action-specific emissions reductions that should qualify for registration.

1. Can “ownership” of the reductions be clearly established?

Yes. It appears that DOE is clear that the producer of the coal ash is the entity responsible for the GHG reductions, and would have the rights of ownership unless explicitly transferred to an end-user. At F.R. 15167, in introducing the view that some action-specific reductions might not be eligible for registration, DOE writes that “In some cases they might be reported as “offsets” under the revised guidelines, if the reporting entity enters into an agreement with the entity directly responsible for the reductions.” Also, at F.R. 15168, DOE writes that “In theory, such reductions might be reported as offsets, but this would require an agreement between the manufacturer and the end-user ...”

Having the producer of the coal ash as the owner of the GHG reductions (unless transferred by agreement) is entirely consistent with DOE’s general approach for determining the entity responsible for emission reductions. In section 300.8(k), DOE states that “The entity that DOE will presume to be responsible for emission reduction, avoided emission or sequestered carbon is the entity with financial control of the facility, land or vehicle which generated the reported emissions, generated the energy that was sold so as to avoid other emissions, or was the place where the sequestration action occurred.” As this concept is applied to “green power” producers (page 270, section 2.4.6 of draft Technical Guidelines), it is the energy generator that is potentially eligible for reporting emissions reductions. similarly, for coal ash and other CCPs, the producer of the coal ash is the first “owner” of any potential reductions. Of course, agreements with end-users could shift this ownership, but such agreements only reinforce rather than change the concept of first ownership.

2. Is the GHG intensity of the product or activity at its source clearly and transparently quantifiable?

Yes. CCPs are a zero-intensity product. They are produced concurrent with the combustion of the coal. All of the Btu and associated GHG emissions associated with the collection and sequestration from the flue gases have already been counted as part of the fuel combustion. Even when the CCP is a flue gas desulfurization (FGD) product, DOE’s methodologies take into account the additional energy required to run the scrubber unit as well as non-combustion related CO₂ emissions arising from sorbent reactions in the FGD units.

Thus, at the point of collection, CCPs represent no incremental Btu or GHG emissions. From there, CCPs are either beneficially used in some end-use application or are disposed of, typically in landfills. If they are disposed in landfills, then energy (and the associated GHG emissions) will be needed, either as electricity used and/or diesel and other fuels. The electric energy would most likely already be accounted for in the reporter's plant fuel consumption for electric power; if diesel and other fuels, then the emissions might not be counted under *de minimus* exclusions.

In any event, this incremental disposal energy is likely to be small relative to the embedded energy and GHG savings represented by the CCPs potential use. Similarly, the transportation of CCPs (with their associated energy and CO₂ emissions) to their end-markets is not likely to be significantly different from the energy and CO₂ emissions associated with transporting the "but for" materials. In general, these small effects, if any, can be ignored and should not change the initial presumption that CCPs represent a zero-intensity product.

3. *If the GHG reductions are dependent upon the distribution across end-use markets, is there credible information on sales to these various end-use markets?*

Yes. CCPs have a variety of characteristics that make them an attractive product in many different end-use applications. Depending upon the end-use application, the energy savings and associated GHG reductions of CCP use is seen to vary tremendously.

With such a wide range of end-uses and associated GHG impacts, it would not be credible to assume that CCP usage can be reported on a "typical" or "average" basis. DOE should expect a higher level of specificity from its reporters regarding end-uses.

The efforts undertaken by the American Coal Ash Association in recent years bestows a high level of confidence our knowledge regarding end-use markets for CCPs. In their annual CCP survey, they have worked to improve the specificity of their market and product definitions, as well as the survey dissemination and response. As a result, for the 2003 Annual Survey, all of the CCP use has been identified by the type of CCP (fly ash, bottom ash, etc.), and over 95 percent according to the end-use markets. This is a high level of certainty, and leads us to conclude that the reporting framework is in place and is working to produce end-use information of high quality.

4. *In an end-use market, is there a credible methodology for calculating GHG reductions?*

Yes. Table 3 of the Roewer-Klein paper – *Estimating GHG Savings from Use of Coal Combustion Products: Methodology and Results for 2000-2003* – is especially relevant to the formulating of an appropriate §1605(b) reporting protocol for CCPs. That table, reproduced here as Figure 2, combines the information on the "but for" products that were displaced and in what proportion, together with the associated energy and CO₂ emissions for each, to develop a set of per-ton factors to be applied to the categories in the ACAA annual surveys of CCP use. We urge DOE to evaluate and adopt these factors.

Using the estimates developed in Figure 2, a §1605(b) reporter could report on the energy and CO₂ avoidances associated with the use of CCPs, using the very same categories used in responding to the ACAA annual survey. For example, one ton of fly ash used in "Concrete/Concrete Products/Grout" end-use category would avoid the consumption of 4.992 million Btu, and avoid 0.93285 tons of CO₂. The reporter would then take the number of tons of fly ash sold into this end-use market to calculate the energy and CO₂ reductions associated with this activity.

5. *If the GHG reductions are dependent upon the usage pattern within end-use markets, is there credible information on the usage patterns of end-users?*

FIGURE 2
ENERGY AND CO₂ FACTORS BY CCP TYPE AND END-USE

CCP End-use	1000 Btu avoided per ton of CCPs					Tons CO ₂ avoided per ton of CCPs				
	Fly Ash	Bottom	Boiler Slag	FGD	FBC Ash	Fly Ash	Bottom	Boiler Slag	FGD	FBC Ash
		Ash		Material			Ash		Material	
Concrete/Concrete Products/Grout	4,992.1	54.6	54.6	54.6	54.6	0.93285	0.00565	0.00565	0.00565	0.00565
Cement/Raw Feed for Clinker	0.0	0.0	0.0	0.0	0.0	0.00000	0.00000	0.00000	0.00000	0.00000
Flowable Fill	5,491.3	5,491.3	5,491.3	5,491.3	5,491.3	1.02613	1.02613	1.02613	1.02613	1.02613
Structural Fills/Embankments	54.6	54.6	54.6	54.6	54.6	0.00565	0.00565	0.00565	0.00565	0.00565
Road Base/Sub-base/Pavement	58.9	58.9	58.9	58.9	58.9	0.00595	0.00595	0.00595	0.00595	0.00595
Soil Modification/Stabilization	2,251.2	2,251.2	2,251.2	2,251.2	2,251.2	0.41822	0.41822	0.41822	0.41822	0.41822
Mineral Filler in Asphalt	0.0	0.0	0.0	0.0	0.0	0.00000	0.00000	0.00000	0.00000	0.00000
Snow and Ice Control	136.7	136.7	136.7	136.7	136.7	0.01943	0.01943	0.01943	0.01943	0.01943
Blasting Grit/Roofing Granules	136.7	136.7	136.7	136.7	136.7	0.01943	0.01943	0.01943	0.01943	0.01943
Mining Applications	363.9	363.9	363.9	363.9	363.9	0.05941	0.05941	0.05941	0.05941	0.05941
Wallboard	230.7	230.7	230.7	230.7	230.7	0.02719	0.02719	0.02719	0.02719	0.02719
Waste Stabilization/Solidification	2,745.7	2,745.7	2,745.7	2,745.7	2,745.7	0.51307	0.51307	0.51307	0.51307	0.51307
Agriculture	68.3	68.3	68.3	0.0	68.3	0.00971	0.00971	0.00971	0.00000	0.00971
Aggregate	58.9	58.9	58.9	58.9	58.9	0.00595	0.00595	0.00595	0.00595	0.00595
Miscellaneous/Other	672.2	672.2	672.2	672.2	672.2	0.12010	0.12010	0.12010	0.12010	0.12010

Yes. In general, the sale of an energy-saving product to an end-user is no guarantee that it will be used, and if it is used, how often. Additionally, the permanence of the end-product is uncertain. For example, when a compact fluorescent lamp is sold, one cannot tell *a priori* that the lamp will even be installed, or if installed how many hours per day it will be used and how long it will last. In situations like these, the reporter needs a credible monitoring and/or sampling procedure to substantiate the estimates of energy and GHG savings.

With CCPs, these uncertainties are not applicable. The various end-use categories in the ACAA survey all represent uses where the materials are used, and where stockpiles are typically of few enough days supply that inventory turnover lag can be reasonably disregarded and immediate displacement can be assumed. And unlike compact fluorescent lamps, where the GHG savings accrue only when operated, the savings from CCP use comes from displacing other materials with their own embedded energy and GHG footprint; the CCP savings are achieved concurrent with their initial use.

Conclusion: The General Framework is Applicable to CCPs

The five-step methodology described a general framework for reporting action-specific GHG reductions. As applied to CCP use, the issues of concern are clearly satisfied. The survey methods implemented by the ACAA, and the GHG estimation methodology described in the attached Roewer-Klein paper, provide a solid basis for reporting and registering these action-specific emissions reductions. DOE should, therefore, revise its guidelines and allow for registration of GHG reductions resulting from coal ash reuse.

**ATTACHMENT TO
COMMENTS OF THE
UTILITIES SOLID WASTE ACTIVITIES GROUP**

**ESTIMATING GHG SAVINGS FROM USE OF COAL COMBUSTION
PRODUCTS: METHODOLOGY AND RESULTS FOR 2000-2003**

by

James Roewer
Utility Solid Waste Activities Group (USWAG)

and

Daniel E. Klein
Twenty-First Strategies, LLC

June 2005

ESTIMATING GHG SAVINGS FROM USE OF COAL COMBUSTION PRODUCTS: METHODOLOGY AND RESULTS FOR 2000-2003

June, 2005

James Roewer
Utility Solid Waste Activities Group (USWAG)
Washington, D.C.

phone: 202-508-5645
fax: 202-508-5150
jim.roewer@uswag.org

Daniel E. Klein
Twenty-First Strategies, LLC
McLean, Virginia

phone: 703-893-8333
fax: 703-893-8813
dklein@21st-strategies.com

ABSTRACT

It is well known that use of coal combustion products (CCPs) to displace portland cement avoids substantial CO₂ emissions, both from the energy savings and from the limestone calcination avoided. However, as annual CCP surveys conducted by the American Coal Ash Association (ACAA) show, there are many other categories of CCP use, and many of these other uses also avoid the energy consumption and GHG emissions associated with production and use of other virgin materials. Although the CO₂ tonnage savings from these other uses are likely much less than those from cement displacement, they are collectively significant.

The Coal Combustion Products Partnership (C2P2) program is a cooperative effort of the U.S. Environmental Protection Agency (EPA) and the coal combustion products (CCPs) industry to help promote the beneficial use of CCPs and the environmental benefits that can result from this beneficial use. These environmental benefits include energy savings and greenhouse gas (GHG) emission reductions from no longer needing to produce the virgin materials now displaced by CCPs.

To promote the goals of the C2P2 program, we want to be able to quantify the GHG benefits of *all* CCP uses, in order to enable CCP sellers and users to identify the climate-related benefits of their activities. This paper develops and describes a methodology for estimating the GHG savings that arise from use of coal combustion products (CCP) in a variety of end-use applications. For each category of CCP use (as defined in the ACAA Annual CCP Survey), we describe our understanding of the “but for” activities avoided by the beneficial use of CCPs, together with the data sources used in quantifying the savings.

We then apply these methodologies to the ACAA Surveys for the years 2000–2003 to estimate total CCP-related GHG savings for those years. In the year 2000, the 32.2 million tons of CCP use avoided approximately 12.2 million tons of CO₂. CCP usage has increased since then, such that by 2003, 46.4 million tons of CCPs avoided an estimated 14.7 million tons of CO₂.

This methodology provides a useful framework for understanding both the energy and GHG benefits of expanded CCP use. For each type of CCP in each end-use application, we develop per-ton estimates of both the avoided Btu consumption and CO₂ emissions.

BACKGROUND

For decades, coal has been the dominant source of electricity in the United States. As it is abundant, geographically widespread, and inexpensive to mine, coal has been the energy source powering more than

half of all electricity use since 1950.³ Indeed, the availability of low-cost electricity has accelerated the electrification of our energy system, with an ever-growing share of our energy use comprised of electricity.⁴

Being comprised of both organic and inorganic materials, the combustion of coal creates large quantities of fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) material.⁵ The ash content of coal produced in the U.S. averages nearly nine percent, and the additional materials used in FGD processes are also substantial.⁶ Collectively, it is estimated that 121.7 million tons of these coal combustion products (CCPs) were produced in the U.S. in 2003, according to the annual surveys conducted by the American Coal Ash Association (ACAA).⁷

For many years, particularly early in the electric power industry's history, CCPs were looked upon as a by-product needing disposal. In recent years, there has been growing awareness that productive use of CCPs provides many environmental and financial benefits. Utilization helps reduce greenhouse gas emissions (associated with the production of the materials now avoided), creates revenue for utilities, and reduces the need for land for disposal and, in turn, corresponding disposal costs. Further, these factors reduce the cost of electricity to the public, commerce and industry, which leads to greater economic growth. Finally, utilization reduces the volume of solid waste disposed and the volume of natural materials needed to be mined or otherwise obtained for construction purposes. In this regard, utilization of coal combustion products has a strong environmental benefit.⁸

CCPs are the fourth largest volume mineral resource produced in the United States. According to the ACAA, about 46.4 million tons of CCPs found beneficial use in 2003.⁹ This represents a substantial 44 percent increase over 2000 levels; it is thought that this increase is due both to improved survey reporting and to higher rates of CCP use. Over one-fourth of this usage was identified as "concrete, concrete products, and grout," and the rest was found among a number of other end-uses.

The Coal Combustion Products Partnership (C2P2) program is a cooperative effort of the U.S. Environmental Protection Agency (EPA) and the coal combustion products industry to help promote the beneficial use of CCPs and the environmental benefits that can result from this beneficial use. These environmental benefits include avoided energy use and GHG emission reductions from no longer needing to produce the virgin materials now displaced by CCPs.

³ Over the 1950-2000 period, coal was the source of over 51 percent of all kilowatt-hours generated in the U.S., ranging from 44 to 57 percent in individual years. See U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 2000*, Table 8. Report No. DOE/EIA-0384(2000). August 2001. <http://tonto.eia.doe.gov/FTPROOT/multifuel/038400.pdf>.

⁴ In 1960, 18.1 percent of total energy consumption was in the form of energy input to electric utilities. By 1999, while total energy consumption more than doubled, 34.9 percent of this larger amount went into the generation of electric power. Developed from U.S. Department of Energy, Energy Information Administration, *State Energy Data Report 1999*. Washington DC: DOE/EIA Report No. DOE/EIA-0214(99), Tables 11, 14, May 2001, <http://eia.doe.gov/pub/state.data/pdf/sedr.pdf>.

⁵ Coal burned in fluidized bed combustors (FBC) also create ash, and beginning in 2002 was accounted for separately in the American Coal Ash Association (ACAA) annual survey.

⁶ In the year 2000, the ash content of coal received at electric utilities averaged 8.84 percent by weight. U.S. Department of Energy, Energy Information Administration, *Coal Industry Annual 2000*, Report No. DOE/EIA-0584(2000), January 2002, Table 106, page 241.

⁷ <http://tonto.eia.doe.gov/FTPROOT/coal/05842000.pdf>. With nearly one billion tons on coal consumed that year for electricity generation, the residual ash alone amounted to about 88 million tons.

⁸ American Coal Ash Association, *2003 Coal Combustion Product (CCP) Production and Use*, [http://www.acaa-usa.org/PDF/2003_CCP_Survey\(10-1-04\).pdf](http://www.acaa-usa.org/PDF/2003_CCP_Survey(10-1-04).pdf).

⁹ Text adapted from American Coal Ash Association, *Who is ACAA?*, <http://www.acaa-usa.org/who.htm>.

⁹ American Coal Ash Association, *2003 Coal Combustion Product (CCP) Production and Use*, [http://www.acaa-usa.org/PDF/2003_CCP_Survey\(10-1-04\).pdf](http://www.acaa-usa.org/PDF/2003_CCP_Survey(10-1-04).pdf).

To promote the goals of the C2P2 program, we want to be able to quantify the GHG benefits of *all* CCP uses, in order to enable CCP sellers and users to identify the climate-related benefits of their activities. To that end, this paper develops and describes a methodology for estimating the GHG savings that arise from use of coal combustion products (CCP) in a variety of end-use applications. We then apply these methodologies to the ACAA Surveys for the years 2000–2003 to estimate total CCP-related GHG savings for those years.

METHODOLOGY FOR DEVELOPING ESTIMATES

In developing estimates of energy and GHG emissions saved by using CCPs, we implemented a five-step methodology:

1. ***Assumed “But For” Materials.*** For each of the CCP uses in the ACAA Survey, we first identify the “but for” case; that is, what other materials would have had more demand and consumption *but for* the use of the CCPs. For example, in the category “concrete, concrete products, and grout,” if the flyash portion of the CCPs had not been used, the “but for” case would have been greater use of portland cement, along with its energy use and CO₂ emissions associated with its production.

CCPs have a variety of uses. For some CCP uses defined in the ACAA Survey, there may be more than one “but for” material displaced. In such cases it is necessary to judge how much of each material might reasonably be displaced.

For some of the “but for” products, there may be inadequate publicly available production and/or fuel consumption data to enable an estimate of avoided impacts of the specific “but for” materials. For such products, it is necessary to identify and use a proxy product or industry, where it is believed that the energy use and GHG emission profile is comparable to the “but for” materials.

Also, we need to determine whether a conversion ratio other than one-for-one is appropriate; that is, whether the CCPs displaced the “but for” material at a ratio either more or less than one ton of CCPs per ton of displaced material.

2. ***Developing Per-Ton Energy Estimates for the “But For” Products.*** Next, we develop per-ton energy estimates for the various “but for” products (or their proxies) that CCPs have displaced. We identify the energy use by type of fuel for each product, and then convert the physical units of energy into Btu using each fuel’s average energy content.
3. ***Calculate the Per-ton CO₂ Emissions for the “But For” Products.*** Next, we estimate the CO₂ emissions associated with the production of the various “but for” products. These avoided CO₂ emissions are the sum of the emissions from the fuels consumed, plus any CO₂ emissions released in the calcination processes.
 - a. Each of the various types of fuel consumed in the production of the various “but for” products has a different carbon content, leading to different rates of CO₂ emitted per million Btu.
 - b. When CCPs are used in place of cement, there are additional CO₂ savings associated with avoiding the calcination process (and associated CO₂ release) in the kilns.¹⁰

¹⁰ We note that some CCP uses substitute for “aglime” or “agricultural lime” in adjusting soil acidity, providing calcium and /or magnesium, and maintaining a proper environment for organic materials to decompose. Aglime is essentially a pulverized limestone product, is distinct from manufactured lime, and is not manufactured in kilns with associated CO₂ releases.

4. ***Calculate the Per-ton Energy and CO₂ Factors for each CCP Type and End-Use.*** For each CCP type and end-use, we know have developed estimates of which “but for” products were displaced and in what proportion, and the associated energy and CO₂ emissions for each. These can now be combined into a set of per-ton factors to be applied to the categories in the ACAA annual surveys of CCP use.
5. ***Calculate the 2000-2003 CO₂ Savings from CCP Use.*** Lastly, for each of the major categories of CCP use, multiply the tonnage of CCP use by the replacement ratio (if any), and multiply by the per-ton estimates of CO₂ savings (both from energy savings and avoided calcination, if any).

There can also be energy and CO₂ savings when the *transportation* of CCPs is less than that for the “but for” materials. For example, if crushed stone had to be hauled an average of thirty miles, but CCPs only traveled an average of ten miles, then each ton of CCP use would also save the energy and CO₂ emissions associated with avoiding 20 extra miles of haulage. However, we have no basis for assuming that CCP haulage is either longer or shorter than the “but for” materials. Accordingly, our methodology generally does not assume either an advantage or disadvantage to CCP haulage, and no estimates on potential savings are developed here.

The following sections describe in greater detail the assumptions and data used to implement this methodology. Table 1 summarizes the assumptions made for the “but for” materials that were identified for each category of CCP use. In Appendix B, Tables B-1 through B-6 describe the calculations entailed in the development of the CO₂ intensity factors for each of the materials displaced by CCP use, and these in turn are summarized in Table 2.

1. ASSUMED “BUT FOR” MATERIALS

The first step in the methodology was to identify the “but for” condition for each category of CCP use. That is, what materials would have had more demand *but for* the use of the CCPs?

In this effort, we were assisted by the staff of the American Coal Ash Association (ACAA) and several of their members. Each year, the ACAA sends out survey forms to collect data of types and quantities of CCPs used in a variety of end-use applications. Our methodology seeks to conform to the ACAA Survey categories, so as to ensure consistency with industry practice and to facilitate estimates of CO₂ savings as future year data are collected.

We used the results of the ACAA surveys for the calendar years 2000 through 2003. Beginning with the 2002 data year, the ACAA survey form was modified, adding some categories and making other refinements so as to better capture the growing volume and variety of CCP uses, and to more closely parallel data gathered by producers for Toxic Inventory Release (TRI) reporting. For our purposes here, the major change is that in the various usage categories for CCPs, a survey question for “Aggregate” was added beginning in 2002. In prior years, CCP use as aggregate was likely reported in various of the other use categories, such as “Concrete” and “Miscellaneous.” Our methodology adapts to this change after 2001; however, while the total uses and CO₂ avoidances are comparable across years, the subtotals for individual uses may reflect this recategorization.

Additionally in the ACAA survey, fluidized-bed combustor (FBC) ash was separately reported beginning in 2002, whereas in previous years it had probably been grouped in with fly ash tonnages. Further, beginning in 2002, FGD materials, which had previously been undifferentiated by type, were reported in four categories – FGD Gypsum, FGD Material Wet Scrubbers, FGD Material Dry Scrubbers, and FGD Other. These other changes to the ACAA survey added detail to their report, but did not necessitate modifications to our CO₂ avoidance methodology.

For each category in the ACAA survey, we have made the following assumptions regarding a reasonable “but for” condition had CCPs not been used. Table 1 summarizes these assumptions for each of the CCP use categories.

Concrete, Concrete Products, & Grout

The ACAA survey methodology defines the “Concrete/Concrete Products/Grout” category to include CCPs used in the making of concrete for construction or for manufacturing products and in the making of grouts. (Prior to the 2002 survey, this category was titled “cement, concrete, & grout”.) This category usually denotes supplies to the Ready-Mix concrete industry, where CCPs substitute for cement. This category does not include CCPs used in Flowable Fills; that category is discussed later.

The “Concrete/Concrete Products/Grout” category is the largest of the various categories of CCP use. In the 2003 ACAA survey, this category accounted for 12.7 million tons of CCP use, over one-fourth of all CCP uses. Of this amount, over 90 percent was comprised of fly ash use, with the remaining tonnage being primarily bottom ash and FGD materials. The fly ash is used to replace cement, while the rest is typically used to replace sand.¹¹ Accordingly, for this analysis, we develop separate “but for” uses for the fly ash and non-fly ash applications.

Fly Ash. When fly ash is added to the concrete mix, some of the cement can be eliminated. Mechanically, fly ash particles are small and spherical, allowing them to fill voids and provide a “ball-bearing” effect that allows less water to be used. Chemically, fly ash reacts with excess lime that is created when cement is mixed with water, creating more of the durable binder that holds concrete together. The resulting product is concrete that is more durable and stronger over time than concrete made with cement alone. The fly ash provides benefits including decreased permeability, increased long-term strength, reduced damage from heat of hydration, and increased resistance to sulfate and other chemicals.¹²

The replacement ratio of fly ash for cement varies according to specific properties of the fly ash and the desired end-use properties (e.g., strength, durability, weight, density) of the concrete. According to Russell Hill of Boral Limited (an international construction and building materials supplier), a ratio of 1.00 to 1.25 tons of fly ash per ton of cement replaced is reasonable for many fly ashes, particularly where equal compressive strength is sought. For some fly ash a ratio higher than 1.25:1 may be needed for strength, but for durability (ASR sulfate resistance, etc.) the replacement value may be slightly less than 1:1.¹³

According to Rich Halverson of ISG Resources (a supplier of fly ash to the concrete industry), most Ready-Mix operations will look at ash on a 1:1 ratio. Not too many will start out assuming a replacement rate greater than 1:1, though some performance concrete applications may end up having higher replacement rates. In either case, with the advent of water reducers, many Ready-Mix producers will use more water reducer to gain comparable performance to a non-ash mix rather than increase the ash content beyond 1:1.¹⁴

Taken together, these observations suggest that a ratio of 1.00 to 1.25 tons fly ash per ton of cement covers most of the applications in this use category. Further, the lower end of this range appears to be more common. Accordingly, for our analysis we have assumed a replacement ratio of 1.1 tons fly ash per ton of cement replaced.

Non-Fly Ash CCPs. As noted, bottom ash and FGD materials are typically used in this category to replace sand. As a proxy measure we will look to the Construction Sand & Gravel Mining industry (NAICS 212321), at a one-for-one tonnage replacement ratio.

¹¹ Tarunjit Butalia, Ohio State University, personal communication, June 25, 2003.

¹² American Coal Council and American Coal Ash Association, *Coal Ash Fact Sheet*, undated, <http://www.acaa-usa.org/PDF/ACCACAA%20Ash%20Fact%20Sheet.pdf>.

¹³ Russell Hill, Boral Material Technologies, Inc., personal communication, June 30, 2003.

¹⁴ Rich Halverson, ISG Resources, personal communication, June 30, 2003.

Cement/Raw Feed for Clinker

The ACAA survey methodology defines the “Cement/Raw Feed for Clinker” category to include CCPs used by manufacturers to produce cement.

The usual primary raw materials for manufacturing cement are limestone or marl, shale or clay, sand, mill scale from steel rolling mills, and gypsum. Alternatives include CCPs, slag from steel furnaces and iron foundries, and spent dust and sand from foundries. Many different combinations of these materials can be used as long as the correct chemistry is achieved. While there are a few exceptions, most CCP's can be used in the manufacture of cement. For example, one ton of coal ash and one ton of sand can replace two tons of clay or shale in the process.¹⁵

The four primary elements required to produce cement are calcium (Ca), silica (Si), aluminum (Al), and iron (Fe). Fly ash and bottom ash can be used as a source of silica, aluminum, and iron. Generally, though, coal ash is used at cement plants as an alumina source. Bottom ash from the same type of boiler will have similar chemistry to fly ash, but will require additional processing. Fly ash is as fine as or finer than kiln feed, and does not require additional grinding for cement manufacturing. However, bottom ash, because of its larger size, must be ground before it is used as a raw feed material.

Attaining the correct chemistry in the cement mix limits the use of certain CCPs, particularly those with high content of iron, sulfur or alkalis. When the iron content of the coal ash is greater than about 8 percent, the tonnage that can be used by a cement plant may be limited. And since iron in coal ash is generally proportional to the sulfur content of the coal, ash from high sulfur coals is more likely to be high in iron and thereby limited in the amount that can be used for this application. Conversely, the low iron content of coal ashes from low sulfur coal allows the use of significant quantities in the mix. In another limitation, fly ash from cyclonic boilers burning Powder River Basin (PRB) coals usually cannot be used in cement manufacturing due to high sulfur and alkali (sodium and potassium) content. In general, cement plants producing low alkali cement are limited in their ability to use CCPs, as their processes are sensitive to alkali levels in the ash.

The carbon content of the fly ash (often measured by the loss on ignition, or “LOI”) can have both positive and negative effects when used as a raw material in cement manufacturing.

- By providing carbon, high LOI fly ashes used as kiln feed can reduce the amount of other fuels required to produce clinker. Alternatively, if the kiln throughput was constrained by coal mill or ID fan capacity, then high LOI fly ashes could facilitate increased clinker production. The LOI in fly ash is fixed carbon, which has an ignition temperature of about 850° C. This temperature is reached at about the third stage in a preheater kiln. Because of the relatively low flue gas temperature, the combustion may stop at carbon monoxide, increasing carbon monoxide (CO) emissions from the kiln. However, experience has been only slight increases in CO. One problem, kiln instability, has been encountered when more than 15 percent of the fuel for a preheater kiln comes from the carbon in kiln feed fly ash. Very high (>30 percent) LOI fly ash has been placed on the feed shelf of a preheater kiln to recover the energy better, but the carbon burned in the load causes localized reducing conditions, which increased sulfur volatilization and buildup in the tower. Insufflation of high LOI fly ash into the riser duct of a preheater or precalciner kiln is the better approach for high LOI fly ash. If the total carbon in the fly ash is too high, insufflation into the burning zone is another possibility.
- Although the high LOI fly ashes could reduce other fuel use, particularly coal, the net effect on CO₂ emissions could be an increase. The LOI in the fly ash (on a moisture and ash-free basis) is

¹⁵ Information in this section draws largely upon personal communications and written materials supplied by Rick Haverland of MRT (a CEMEX Company), August 2004, and other materials from the American Coal Ash Association.

about 99 percent carbon, while coal is closer to about 70 percent. The additional CO₂ emissions from the LOI combustion in the fly ash – relative to either landfilling or a non-combustion use of the CCPs – would be more than the CO₂ emissions avoided from the coal or other fuels avoided.

- Fly ash is generally so fine it tends to increase raw mill production and decrease maintenance costs. Conversely, bottom ash is very hard to grind and are very abrasive. When bottom ash is used in the raw mill the raw mill production goes down and maintenance costs go up. Because of the sand required with the coal ash to replace clay or shale, coal ash is usually not used to replace clay or shale when the cement plant has a roller mill for raw material grinding. A roller mill is not effective at grinding sand, and the sand causes excessive wear of the roller mill.

For this analysis, the use of CCPs would most likely displace shale or clay, although a broader range of substitutes is sometimes involved. However, there is a question as to whether the CCPs are displacing materials that would not otherwise be produced. Much of the shale or clay that is displaced would have originally been produced as overburden in limestone production, and as such would not require much incremental energy. When the CCPs are displacing iron sources, about 90 percent of the displacement is of millscale, an oxide or iron which is typically recycled as small grey flakes as a ferrous feed for the sinter plant; this by-product from steel production could generally not be considered a virgin material.

Two other considerations complicate the “but-for” analysis for this category. One is the LOI level – when it is high, the CCP use displaces a portion of the fuel used in the kiln. Potentially offsetting this is a transportation fuel use difference – by-product shale or clay is typically produced much closer to the kiln, and as such tends to consume less transportation fuel than would CCPs used for the same purpose.

Given that much of the displaced material in this category is non-virgin material, the CO₂ savings are likely to be low. Additionally, while there may be some CO₂ savings from use of high-LOI CCPs, these would tend to be offset by CO₂ penalties associated with the often-higher CCP transport distances. Accordingly, for this analysis, we are assuming that non-virgin materials represent the “but-for” materials, and we do not compute any overall CO₂ benefits for CCP use in this category.

Flowable Fill

The ACAA survey methodology defines the “Flowable Fill” category to include CCPs used in applications such as Controlled density fill, Controlled low strength materials, Flowable fly ash, and Lean mix backfill.

We have assumed that cement is replaced, at a one-for-one tonnage replacement ratio.

Structural Fills/Embankments

The ACAA survey methodology defines the “Structural fills/ Embankments” category to include CCPs used as a structural fill or embankment which is defined as an engineered fill with a projected beneficial end use that is typically constructed in layers of uniform thickness and compacted to a desired unit weight in a manner to achieve compaction requirements, strength, and hydraulic conductivity. This could include situations where CCPS are used as part of a disposal facility for their engineering properties and are not considered as disposed.

CCP use in this category typically displace a variety of soils, including sand, clay, silt, and gravel.¹⁶ For this analysis, we have assumed that Construction Sand & Gravel (NAICS 212321) is replaced, at a one-for-one tonnage replacement ratio.

¹⁶ Tarunjit Butalia, Ohio State University, personal communication, June 25, 2003.

Road Base/Subbase/Pavement

The ACAA survey methodology defines the “Road Base/Sub-base/ Pavement” category to include CCPs used alone or in combination with other materials in the construction of the base or sub-base and pavement for roads.

We have assumed that crushed stone (NAICS 212319) is replaced, at a one-for-one tonnage replacement ratio.

Soil Modification/Stabilization

The ACAA survey methodology defines the “Soil modification/stabilization” category to include CCPs used for soil modification which is defined as a change to the physical or chemical characteristics of soils; any change to in-situ soils that results in immediate effects that can expedite construction operations.

CCP use here usually displaces use of agricultural lime, cement, and/or cement kiln dust. Agricultural lime and cement (which require virgin materials) tend to be more commonly used than kiln dust (not requiring virgin materials). For this analysis, we have assumed that only 40 percent of the CCP usage displaces agricultural lime, another 40 percent displaces cement use, and the remaining 20 percent displacing cement kiln dust (and not reducing CO₂ emissions). We assume a one-for-one tonnage replacement ratio for all materials. For the agricultural limestone, we will use the Industrial Sand Mining Industry (NAICS 212322) as a proxy measure, since that is thought to better represent the pulverization energy needs better than other categories that merely crush the minerals.

Mineral Filler in Asphalt

The ACAA survey methodology defines the “Mineral Filler in Asphalt” category to include fly ash used in bituminous asphalt mixtures to compensate for deficient fines in the aggregate or to impart other physical characteristics.

CCP use here typically displaces cement kiln dust or marble dust in asphalt mixes, and sometimes in plastics. The displaced materials are typically not virgin materials (and not reducing CO₂ emissions).

Snow and Ice Control

The ACAA survey methodology defines the “Snow and Ice Control” category to include bottom ash or other CCPs used as an alternative to sand for road de-icing operations and skid control.

CCP use here typically substitutes for sand. As a proxy measure we will look to the Industrial Sand Mining industry (NAICS 212322), at a one-for-one tonnage replacement ratio.

Blasting Grit & Roofing Granules

The ACAA survey methodology defines the “Blasting Grit/Roofing Granules” category to include boiler slag used as substitute for sand or oxide abrasives in cleaning of castings, paint removal, etc. and as a filler in roofing shingles.

Most of the CCP use here replaces silica grit as a blasting grit. Smaller amounts replace crushed rock in roofing. As a proxy measure we will look to the Industrial Sand Mining industry (NAICS 212322), and assume that CCP use here replaces industrial sand at a one-for-one tonnage replacement ratio.

Mining Applications

The ACAA survey methodology defines the “Mining Applications” category to include CCPs used in the coal mining industry (surface mining reclamation projects, underground mining projects, etc.) and in other mining industries (such as sand & gravel pits, quarries, etc.).

CCP usage in the mining industry substitutes for a variety of products, depending largely upon the type of mining operation at which they are used.¹⁷

- Probably three-fourths or more of the CCP use has been in surface mining operations, where CCPs are used as a cost-effective, non-toxic material to help reclaim the land to “approximate original contour. We will assume 80 percent of this category’s CCP use is for this. Since the “but for” material is previously mined spoils from other areas of the mine, we do not assume any additional energy or GHG savings from this use.
- The second most prevalent use is in reclaiming abandoned mine lands affected by acid spoil conditions; some displaces agricultural lime (aglime) as a soil amendment for raising the pH of acidic soils, while some displaces clay in sealing off deep acidic layers. For this analysis, we will assume that 10 percent of this category’s CCP use is in abandoned mine land applications. Half of this amount (5 percent of total) displaces aglime; as with the Soil Modification category, we will use the Industrial Sand Mining Industry (NAICS 212322) as a proxy measure, since that is thought to better represent the pulverization energy needs better than other categories that merely crush the minerals. The other half displaces clay as represented by the Clay, Ceramic, and Refractory Minerals Mining Industry (NAICS 212325). Both uses are assumed to be on a one-for-one tonnage replacement ratio.
- Some of the remaining CCPs are used in control of acid mine drainage at active mining operations. Here, it is used as a seal, displacing and generally improving upon lime use. For this analysis, we will assume that 5 percent of this category’s CCP use displaces agricultural lime, on a one-for-one tonnage replacement ratio.
- The remaining CCP use is in underground mining operations for acid mine drainage mitigation and for subsidence control. Here, CCP use typically displaces Shotcrete. We have assumed that cement is replaced, at a one-for-one tonnage replacement ratio.

Summing across all of these mining applications, we arrive at the aggregate assumption that 80 percent of the tonnage does not displace virgin materials, and therefore we do not assign any energy or GHG savings to it. Ten percent of the CCP use displaces agricultural lime, five percent displaces cement, and five percent displaces clay. All are on a one-for-one tonnage replacement ratio.

Wallboard

The ACAA survey methodology defines the “Wallboard” category to include FGD Gypsum used for manufacturing wallboard

CCP usage here typically displaces gypsum. As a proxy measure for mined gypsum, we will look to the “All Other Nonmetallic Minerals Industry” (NAICS 212399). Within this industry group, gypsum (NAICS 2123993) comprises about 10 percent of this category, and is grouped together with diatomite, talc, perlite, and others. We assume that CCP use here replaces “All Other Nonmetallic Minerals” at a one-for-one tonnage replacement ratio.

Waste Stabilization & Solidification

The ACAA survey methodology defines the “Waste Stabilization/Solidification” category to include CCPs used in stabilization or fixation of wastes (such as the treatment of solids from wet scrubbing or other air pollution control processes) or in solidification of wastes (conversion of liquids, slurries or sludge into a material that can be handled more easily).

¹⁷ Information here based upon Kim Vories, U.S. Department of Interior, Office of Surface Mining, personal communication, July 24, 2003.

CCP usage here often displaces use of cement. We have assumed that for 50 percent of the CCP use in this category, cement is replaced, at a one-for-one tonnage replacement ratio, with the other 50 percent not displacing virgin materials (and not reducing CO₂ emissions).

Agriculture

The ACAA survey methodology defines the “Agriculture” category to include CCPs used as a soil amendment, for changing physical and/or chemical characteristics of the soil to improve crop yield. This category does not include CCPs used in the construction of farm roads, feedlots etc.

In the ACAA surveys, most of the CCPs reported for agricultural use are identified as FGD material. Smaller quantities are reported for fly ash and bottom ash. As the FGD materials serve different purposes in this category, our methodology employs different assumptions regarding displaced materials.

The ash materials (the smaller fraction of the CCPs used in agriculture) are typically used as a pH adjustment. Here, we have assumed that agricultural lime is displaced. However, a one-for-one replacement tonnage ratio is probably too optimistic.¹⁸ Class F flyash would likely have very little pH adjustment effect. Class C flyash would be better, but still far from equivalent to lime. FGD materials may have some excess lime, but if scrubber systems are operating efficiently, the lime equivalency of the FGD might be 33 percent or less. Overall, a maximum of 50 percent lime equivalency is likely. Accordingly, for this analysis we assume that ash use displaces agricultural lime on a two-for-one tonnage replacement ratio.

For agricultural applications, FGD gypsum does not displace aglime, as it is not an alkaline material. Instead, it is typically used to amend soils for aeration, soil aggregation, improving water infiltration, and reducing runoff and erosion, thereby promoting root growth and crop yields.¹⁹ Also, some gypsum is used as a sulfur fertilizer, but it is thought that this is a minor use at present. These soil amendment applications are valuable for the farmers, but tend not to displace other materials – i.e., there isn't a “but for” material. Accordingly, our methodology for this category assumes that the FGD materials don't displace anything.

Aggregate

The ACAA survey methodology added this category for the 2002 Survey. Beginning with the 2002 Survey, this category is defined to include CCPs used to manufacture normal-weight or lightweight aggregate including bottom ash, FGD material, or boiler slag used as an aggregate.

In previous years these uses were reported under other categories, most likely “Concrete” or “Miscellaneous/Other.” Accordingly, this survey change represents more of a refinement and articulation of previous data than a reporting of a “new” use for CCPs. For our methodology, we have assumed that crushed stone (NAICS 212319) is replaced, at a one-for-one tonnage replacement ratio.

Miscellaneous & Other

The ACAA survey methodology defines the “Miscellaneous/Other” category to include CCPs used as fillers in paints, coatings, metals, plastics and applications not identified for the various categories provided. This would include down-hole oil field applications, as well.

The oil field applications are thought to comprise only about ten percent of the CCP in this category, and mainly found in Texas, Oklahoma and neighboring areas. In these applications, cement is displaced, on a one-for-one basis.²⁰

¹⁸ Bob Brown, Ohio Coal Development Office, personal communication, June 25, 2003.

¹⁹ Warren Dick, School of Natural Resource, Ohio State University, personal communication, October 21, 2004.

²⁰ Dave Goss, American Coal Ash Association, personal communication, October 22, 2004

Most of the CCP usage – perhaps 90 percent – in this category is for fillers in paints and other materials. Here, CCPs tend to substitute for a wide range of materials such as calcium carbonate, clay, talc, sand, and walnut shells. Generally, these are materials that are mined and finely ground, but not otherwise processed or converted. For estimating CO₂ savings, we assume that these CCP uses replace “Industrial Sand Mining” (NAICS 212322) at a one-for-one tonnage replacement ratio.

2. DEVELOPING PER-TON ENERGY ESTIMATES FOR THE “BUT FOR” PRODUCTS

For each material that is displaced by CCPs, our methodology next develops per-ton estimates of the energy avoided by CCP use. Since different fuels have different CO₂ intensities (as measured by lbs. CO₂/MMBtu), it is also necessary to do this on a fuel-by-fuel basis.

The estimated Btu per ton of *avoided* materials are summarized as part of Table 2. (Note that in order to relate these estimates to the tons of CCP used, one also needs to account for the mix of avoided materials for a given CCP use and whether a conversion ratio other than one-for-one has been assumed.) The data sources and methods used in developing these estimates are described below. Tables B-1 through B-6 in Appendix B describe the calculations entailed in the development of the energy consumption and CO₂ intensity factors for each of the materials displaced by CCP use.

Cement

Data on energy consumption in the cement industry comes from the Portland Cement Association (PCA). In the 2002 edition of their *U.S. Cement Industry Fact Sheet*,²¹ PCA presents data on energy consumption by type of fuel, showing the Btu consumed per “equivalent metric ton” of cement, a measure designed to adjust for import and export trade in cement.

For cement, no conversion from physical units to Btu was needed, as the fuel consumption data in the PCA reports was already expressed as Btu consumed.

Other Commodities

In addition to cement and lime, five other materials displaced by CCPs (“but for” materials) were identified as relevant to our methodology:

1. All Other Nonmetallic Minerals (Incl. Gypsum) (NAICS 212399)
2. Clay, Ceramic, and Refractory Minerals Mining (NAICS 212325)
3. Construction Sand & Gravel Mining (NAICS 212321)
4. Industrial Sand Mining (NAICS 212322)
5. Other Crushed and Broken Stone (NAICS 212319)

For energy consumption used in producing these other commodities, the U.S. Census Bureau seems to have the most useful (and nearly only) data. This is found in their 1997 Economic Census, with reports generally issued beginning in 1999.²² For the mining sector, data are published primarily on the basis of the North American Industry Classification System (NAICS), a successor system similar to but not quite comparable to the older Standard Industrial Classification (SIC) system. Two reports from the 1997 Economic Census-Mining provide the key data on product shipments and fuel consumption.²³

²¹ Portland Cement Association, *U.S. Cement Industry Fact Sheet*, 2002, Table 22.

²² The Economic Census is conducted every five years, covering years ending in 2 or 7. Data from the 2002 Economic Census had not yet been released when this methodology was developed. Beginning late 2004, and continuing through 2006, data from the 2002 Economic Census is being published.

²³ The 1997 Economic Census-Mining has also published about 25 industry-specific reports as part of its industry series; the complete list is available at <http://www.census.gov/prod/www/abs/97ecmini.html>. However, there

- *Product Summary*. U.S. Census Bureau, 1997 Economic Census-Mining, issued June 2001, Report #EC97N21S-PS, <http://www.census.gov/prod/ec97/97n21s-ps.pdf>. Table 1 of this report contains 1997 tonnage production for industries with NAICS codes ranging between 211111 and 213115, sometimes up to a ten-digit NAICS code level.
- *Fuels and Electric Energy Report*. U.S. Census Bureau, 1997 Economic Census-Mining, revised May 23, 2002, <http://www.census.gov/mcd/fuels.html>. Table 3a of this report (<http://www.census.gov/mcd/feetable3a.pdf>) contains 1997 data on consumption of purchased fuels and electric energy, in physical units, for industries with NAICS codes ranging between 211111 and 213115; however, there is no detail below the six-digit NAICS code level.

For these materials displaced by CCPs, the energy consumption is typically reported in terms of physical units such as barrels of distillate, gallons of gasoline, or tons of coal. For our methodology, these physical units need to be converted into millions of Btu (MMBtu). To make these conversions we will use data from the DOE Energy Information Administration's *Annual Energy Review 2000*.²⁴ For most fuels, the Btu per unit remains constant year-to-year. For coal ("other industrial") and natural gas ("sectors other than elec. utilities"), average Btu contents tend to vary slightly from year to year; our analysis will use the values based on 1997 data to be consistent with the Census Bureau information on fuel quantities consumed.

For each of these materials displaced by CCPs ("but for" materials), the methodology was the same. We first listed the energy consumed by type of fuel. These quantities were then converted to Btu using the Btu factors developed from the DOE Energy Information Administration data. Dividing the total Btu by the total product tonnage, we are able to estimate the energy avoided per ton of material displaced by CCP use.

3. CALCULATE THE PER-TON CO₂ EMISSIONS FOR THE "BUT FOR" PRODUCTS

The next step of the methodology converts the avoided material use into avoided CO₂ emissions. There are two parts to this calculation. First, we estimate the avoided CO₂ emissions associated with the avoided energy consumption. Then, for the applications where cement is displaced, there are additional CO₂ savings associated with the avoided calcination that would have been needed for the cement production.

The estimated lbs./CO₂ per ton of *avoided* materials are shown as part of Table 2. (Note that in order to relate these estimates to the tons of CCP used, one also needs to account for the mix of avoided materials for a CCP use and whether a conversion ratio other than one-for-one has been assumed.) The data sources and methods used in developing these estimates are described below. Tables B-1 through B-6 in Appendix B describe the calculations entailed in the development of the energy consumption and CO₂ intensity factors for each of the materials displaced by CCP use.

Per-ton CO₂ Savings from Avoided Energy Consumption

Because different fuels have different GHG intensities, it was necessary to develop coefficients showing the lbs. CO₂ per MMBtu of different fuels. For this we used DOE/EIA's, *Fuel and Energy Source Codes and Emission Coefficients*,²⁵ A few additional adjustments were needed for our purposes:

were two major limitations to using these industry-specific reports rather than the *Product Summary* and *Fuels and Electric Energy Report*. First, the *Fuels and Electric Energy Report* does not include electricity consumption data, often a major portion of total energy use. Second, most of the industry-specific reports where published in 1999; the other two reports were prepared subsequently and show some revisions to the earlier published data.

²⁴ U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 2000*, DOE/EIA-0384(2000), August 2001. Tables A1, A4, A5. <http://tonto.eia.doe.gov/FTPROOT/multifuel/038400.pdf>.

²⁵ U.S. Department of Energy, Energy Information Administration, *Fuel and Energy Source Codes and Emission Coefficients*, <http://www.eia.doe.gov/oiaf/1605/factors.html>. This document is also available as Appendix B to the Long Form Instructions for the §1605(b) Voluntary Reporting of Greenhouse Gases.

- For coal, the CO₂ emissions vary by rank of coal. Here, we used a CO₂ coefficient of 209 lb. CO₂/MMBtu; which is the midpoint of bituminous (205.3) and subbituminous (212.7) values.
- Values for “Waste Fuel” in cement production were based on tire-derived fuel, and are 189.5 lb. CO₂/MMBtu.
- Where “Other fuels” and “Undistributed Fuels” have been included for various mined products, we have assumed that they are primarily petroleum products, with CO₂ factors based on distillate and light diesel (161.4 lb. CO₂/MMBtu).
- Electricity values were based on the average lb. CO₂/MWh for all electricity sold in the U.S. in 2000. Using the DOE/EIA reports *Annual Energy Review 2001* (3,605 billion kWh of end-use in 2000) and *Emissions of Greenhouse Gases in the United States 2001*, Table 10 (616.6 MMTCE from fuels consumed for electric power in 2000), we calculate an average of 1,382.61 lb. CO₂/MWh sold.²⁶ Electricity has an end-use energy value of 3,412 Btu/kWh, yielding a 2000 average of 405.22 lb. CO₂/MMBtu of electric power consumed.²⁷

Additional Per-ton CO₂ Savings from Avoided Calcination

For cement, there are additional quantities of CO₂ avoided from the limestone not calcinated. The process-related non-energy emissions refer to the calcination process, in which calcium carbonate is converted to calcium oxide and CO₂. The CO₂ is typically emitted into the atmosphere, in quantities roughly equal to the amount of CO₂ emitted from the process energy use.

We used the methodologies and data described in EPA’s *Inventory of U.S. Greenhouse Gases Emissions and Sinks: 1990-2000*.²⁸ On pages 3-6 and 3-7 of that report, EPA describes their methodology and references Intergovernmental Panel on Climate Change (IPCC) recommendations. Using an average lime fraction for clinker of 64.6 percent and a constant reflecting the mass of CO₂ released per unit of lime (44.01/56.08), they derive an emissions factor of about 0.507 tons of CO₂ per ton of clinker produced. Since some of the clinker precursor materials remain in the kiln as cement kiln dust (CKD), there are additional emissions. These additional CKD emissions are estimated at 2 percent of the CO₂ emissions from the clinker production, raising the effective emissions factor from about 0.507 to 0.517 tons CO₂ per ton of cement. This EPA methodology equals 1034.2 pounds CO₂/ton cement clinker, slightly more than half a ton CO₂ per ton of cement.

4. CALCULATE THE PER-TON ENERGY AND CO₂ FACTORS FOR EACH CCP TYPE AND END-USE

For each CCP type and end-use, we now have developed estimates of which “but for” products were displaced and in what proportion, and the associated energy and CO₂ emissions for each. These can

²⁶ U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 2001*, Report No. DOE/EIA-0384(2001). November 2002, Table 8.1. <http://tonto.eia.doe.gov/FTP/ROOT/multifuel/038401.pdf>. U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2001*, Report No. DOE/EIA-0573(2001), December 2002, Table 10. <http://www.eia.doe.gov/oiaf/1605/ggrpt/pdf/057301.pdf>. These calculations also use 2204.6 pounds per metric ton and 44/12 tons CO₂ per ton carbon.

²⁷ Alternatively, one could have used the average Btu input per kWh (10,655 in 2000), together with an average CO₂ emissions rate of 129.8 lb. CO₂/MMBtu input for the entire electric power sector in 2000. Both approaches yield the same average rate of 1,382.6 lb. CO₂/MWh in 2000.

²⁸ U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gases Emissions and Sinks: 1990-2000*, USEPA #430-R-02-003, April 15, 2002, pp. 3-5 to 3-11, <http://www.epa.gov/globalwarming/publications/emissions/us2002/index.html>.

now be combined into a set of per-ton factors to be applied to the categories in the ACAA annual surveys of CCP use.

As a simple example, CCPs used in structural fills and embankments have been assumed to displace sand, clay, silt, and gravel. As developed earlier, we have assumed that 100% of this activity would apply to the “but-for” material of Construction Sand and Gravel Mining (NAICS 212321), at a displacement ratio of 1 ton CCP per ton of “but for” material. As seen in Table 2, displacing one ton of Construction Sand and Gravel Mining (NAICS 212321) avoids 54.6 thousand Btu, and 0.00565 tons of CO₂. Accordingly, since we have assumed a 100% use of the but-for material and a one-for-one displacement ratio, the factors for one ton of CCPs used in structural fills and embankments are similarly 54.6 thousand Btu and 0.00565 tons of CO₂.

For those CCP uses where multiple displaced materials are assumed, the calculation is made for each but-for material, and then weighted in proportion to its share of the materials displaced. Additionally, for those situations where the displacement ratio is not one-for-one, the per-ton factors are adjusted accordingly.

The resulting calculations of the factors of energy and CO₂ avoided per ton are shown in Table 3.

5. CALCULATE 2000 – 2003 CO₂ SAVINGS FROM CCP USE

Data on CCP production and use is collected yearly by the American Coal Ash Association (ACAA).²⁹ The results of the ACAA surveys for 2000 through 2003 are tabulated in Appendix A, Tables A-1 through A-4. ACAA data show a total of 32.1 million tons of CCP use in 2000, rising to 46.4 million tons in 2003. The ACAA survey managers believe that this increase is due both to higher rates of CCP use and to improved rates of survey reporting.

As an example, we can illustrate how the estimates of CO₂ avoidances would be developed from the survey results and our methodology. For example, for the CCP use category of Structural Fills, we have assumed that the 4.545 million tons used in 2000 (Table A-1) would be displacing “Construction Sand & Gravel Mining” (Table 1). Because we have also assumed a one-for-one displacement ratio (Table 1), an equal number of tons of virgin material would be displaced. As developed in Table B-4, each ton of “Construction Sand & Gravel Mining” produced consumes an average of about 0.055 MMBtu, and in doing so emits an average of 11.3 pounds (0.00565 tons) of CO₂.

Hence, the year 2000 savings from CCP use in Structural Fills would amount to about:

- 250,000 MMBtu of energy saved (equal to 4.545 million tons * 1.0 [displacement ratio] * 0.055 MMBtu/ton)
- 25,700 tons of CO₂ (equal to 4.545 million tons * 1.0 [displacement ratio] * 11.3 lbs. CO₂/ton / 2000 lbs./ton)

FINDINGS

Table 4 summarizes the CCP use and associated CO₂ benefits for 2000 through 2003; the detailed calculations by CCP use category and type of CCP are shown in Appendix C, Tables C-1 through C-4. As seen, CCP use in “concrete/concrete products/grout” (“cement, concrete, grout” in the 2000 and 2001 surveys) accounts for most of the CO₂ benefits, as that category combines large tonnages, high energy intensity, and associated emissions for calcination. However, other categories of CCP use also replace cement use, and these also account for substantial CO₂ savings. Other categories that replace virgin mined materials having no cement component produce much smaller CO₂ savings.

²⁹ The most recent published survey data is for the year 2003, and is available at [http://www.acaa-usa.org/PDF/2003_CCP_Survey\(10-1-04\).pdf](http://www.acaa-usa.org/PDF/2003_CCP_Survey(10-1-04).pdf).

In the year 2000, the 32.2 million tons of CCP use avoided approximately 12.2 million tons of CO₂. Of this, the amount used in “cement, concrete, and grout” comprised 11.4 million tons of CCPs and avoided about 9.9 million tons CO₂. The remaining CCP use categories collectively comprised 20.8 million tons of CCPs and avoided 2.3 million tons CO₂.

CCP usage in 2001 increased to 37.1 million tons, avoiding an estimated 14.2 million tons of CO₂. Of this, the amount used in “cement, concrete, and grout” comprised 13.6 million tons of CCPs and avoided about 11.5 million tons CO₂. The remaining CCP use categories collectively comprised 23.5 million tons of CCPs and avoided 2.6 million tons CO₂.

CCP usage in 2002 increased to 45.5 million tons, avoiding an estimated 15.1 million tons of CO₂. Of this, the amount used in “concrete/concrete products/grout” comprised 13.1 million tons of CCPs and avoided about 11.7 million tons CO₂.³⁰ The remaining CCP use categories collectively comprised 32.4 million tons of CCPs and avoided 3.3 million tons CO₂.

CCP usage in 2003 showed a further small increase to 46.4 million tons. However, a slightly lower portion of this was used in cement displacement than was observed in 2002, leading to a slightly lower estimated avoidance of 14.7 million tons of CO₂. Of this, the amount used in “concrete/concrete products/grout” comprised 12.7 million tons of CCPs and avoided about 11.4 million tons CO₂. The remaining CCP use categories collectively comprised 33.7 million tons of CCPs and avoided 3.2 million tons CO₂.

Using the results from the 2003 ACAA survey and the associated estimates of CO₂ avoidance, we can also derive some “average” factors for CO₂ emissions avoided when the CCP use is not known exactly:

- For fly ash used in the Concrete/Concrete Products/Grout category, each ton of CCPs avoided an average of 0.933 tons of CO₂.
- For all other non-concrete uses of fly ash, including some use categories also displacing cement, each ton of CCPs avoided an average 0.167 tons of CO₂.
- Across all categories of fly ash use, both concrete and others, each ton of CCPs avoided an average of 0.513 tons of CO₂.
- For CCP uses involving bottom ash, boiler slag, FGD materials, and FBC ash, CO₂ avoidance was much lower, and each ton of these CCPs avoided on average 0.038 tons of CO₂.

Since the average mix of CCP uses shows some shifts year-to-year, it is also the case that these “average” factors for CO₂ emissions will similarly show shifts over time. For example, in 2003, which showed growth in CCP tonnage reported in non-cement applications, the average CO₂ savings per ton of CCP used showed decline from earlier years.

³⁰ Note that compared to 2001, CCP tonnage is a little less but that the CO₂ avoidance is a little more. The reason for this is that the flyash usage increased in 2002, while other CCP use (with much lower CO₂ intensity) either declined or was recategorized into other CCP use categories.

TABLE 1
SUMMARY OF KEY ASSUMPTIONS ON CCP USE

CCP Use Category	Type of CCP	% of CCP replaced	Materials displaced	Assumed "but for" material	tons CCP to tons "but for" Material	1000 Btu per ton CCP	tons CO2 per ton CCP
Concrete/Concrete Products/Grout	fly ash	100%	Cement	Cement	1.1	5,491.3	1.0261
	other CCPs	100%	Sand	Construction Sand & Gravel Mining (NAICS 212321)	1.0	54.6	0.0057
Cement/Raw Feed for Clinker	all types	100%	Other materials	<i>not displacing virgin materials</i>	1.0	0.0	0.0000
Flowable Fill	all types	100%	Cement	Cement	1.0	5,491.3	1.0261
Structural Fills/Embankments	all types	100%	Sand, clay, silt, gravel	Construction Sand & Gravel Mining (NAICS 212321)	1.0	54.6	0.0057
Road Base/Sub-base/Pavement	all types	100%	Crushed stone	Crushed Stone (NAICS 212319)	1.0	58.9	0.0060
Soil Modification/Stabilization	all types	{	40% Agricultural limestone	Industrial Sand Mining (NAICS 212322)	1.0	136.7	0.0194
	all types		40% Cement	Cement	1.0	5,491.3	1.0261
	all types		20% Cement kiln dust	<i>not displacing virgin materials</i>	1.0	0.0	0.0000
Mineral Filler in Asphalt	all types	100%	Cement kiln & marble dust	<i>not displacing virgin materials</i>	1.0	0.0	0.0000
Snow and Ice Control	all types	100%	Sand	Industrial Sand Mining (NAICS 212322)	1.0	136.7	0.0194
Blasting Grit/Roofing Granules	all types	100%	Silica grit	Industrial Sand Mining (NAICS 212322)	1.0	136.7	0.0194
Mining Applications	all types	{	80% Previously mined spoils	<i>not displacing virgin materials</i>	1.0	0.0	0.0000
	all types		10% Agricultural limestone	Industrial Sand Mining (NAICS 212322)	1.0	136.7	0.0194
	all types		5% Shotcrete	Cement	1.0	5,491.3	1.0261
	all types		5% Clay	Clay, Ceramic, & Refractory Minerals (NAICS 212325)	1.0	1,513.8	0.1231
Wallboard	all types	100%	Gypsum	All Other Nonmetallic Minerals (NAICS 212399)	1.0	230.7	0.0272
Waste Stabilization/Solidification	all types	{	50% Cement	Cement	1.0	5,491.3	1.0261
	all types		50% Other materials	<i>not displacing virgin materials</i>	1.0	0.0	0.0000
Agriculture	all ashes	100%	Agricultural limestone	Industrial Sand Mining (NAICS 212322)	2.0	136.7	0.0194
	all FGDs	100%	unamended soils	<i>not displacing virgin materials</i>	1.0	0.0	0.0000
Aggregate	all types	100%	Crushed stone	Crushed Stone (NAICS 212319)	1.0	58.9	0.0060
Miscellaneous/Other	all types	{	10% Cement	Cement	1.0	5,491.3	1.0261
			Calcium carbonate, clay, 90% talc, sand, etc.	Industrial Sand Mining (NAICS 212322)	1.0	136.7	0.0194

TABLE 2
SUMMARY OF BTU CONTENTS AND CO₂ CONTENTS OF MATERIALS DISPLACED

<u>Material Displaced</u>	<u>Savings per ton of displaced materials</u>		
	<u>Btu (1000)</u>	<u>CO₂ (lbs.)</u>	<u>CO₂ (tons)</u>
Cement Manufacture	5491.3	2052.3	1.02613
All Other Nonmetallic Minerals (Incl. Gypsum) (NAICS 212399)	230.7	54.4	0.02719
Clay, Ceramic, and Refractory Minerals Mining (NAICS 212325)	1513.8	246.3	0.12314
Construction Sand & Gravel Mining (NAICS 212321)	54.6	11.3	0.00565
Industrial Sand Mining (NAICS 212322)	136.7	38.9	0.01943
Other Crushed and Broken Stone (NAICS 212319)	58.9	11.9	0.00595
<i>Not displacing Virgin Materials</i>	0.0	0.0	0.00000

TABLE 3
ENERGY AND CO₂ FACTORS BY CCP TYPE AND END-USE

CCP End-use	1000 Btu avoided per ton of CCPs					Tons CO₂ avoided per ton of CCPs				
	<u>Fly Ash</u>	<u>Bottom Ash</u>	<u>Boiler Slag</u>	<u>FGD Material</u>	<u>FBC Ash</u>	<u>Fly Ash</u>	<u>Bottom Ash</u>	<u>Boiler Slag</u>	<u>FGD Material</u>	<u>FBC Ash</u>
Concrete/Concrete Products/Grout	4,992.1	54.6	54.6	54.6	54.6	0.93285	0.00565	0.00565	0.00565	0.00565
Cement/Raw Feed for Clinker	0.0	0.0	0.0	0.0	0.0	0.00000	0.00000	0.00000	0.00000	0.00000
Flowable Fill	5,491.3	5,491.3	5,491.3	5,491.3	5,491.3	1.02613	1.02613	1.02613	1.02613	1.02613
Structural Fills/Embankments	54.6	54.6	54.6	54.6	54.6	0.00565	0.00565	0.00565	0.00565	0.00565
Road Base/Sub-base/Pavement	58.9	58.9	58.9	58.9	58.9	0.00595	0.00595	0.00595	0.00595	0.00595
Soil Modification/Stabilization	2,251.2	2,251.2	2,251.2	2,251.2	2,251.2	0.41822	0.41822	0.41822	0.41822	0.41822
Mineral Filler in Asphalt	0.0	0.0	0.0	0.0	0.0	0.00000	0.00000	0.00000	0.00000	0.00000
Snow and Ice Control	136.7	136.7	136.7	136.7	136.7	0.01943	0.01943	0.01943	0.01943	0.01943
Blasting Grit/Roofing Granules	136.7	136.7	136.7	136.7	136.7	0.01943	0.01943	0.01943	0.01943	0.01943
Mining Applications	363.9	363.9	363.9	363.9	363.9	0.05941	0.05941	0.05941	0.05941	0.05941
Wallboard	230.7	230.7	230.7	230.7	230.7	0.02719	0.02719	0.02719	0.02719	0.02719
Waste Stabilization/Solidification	2,745.7	2,745.7	2,745.7	2,745.7	2,745.7	0.51307	0.51307	0.51307	0.51307	0.51307
Agriculture	68.3	68.3	68.3	0.0	68.3	0.00971	0.00971	0.00971	0.00000	0.00971
Aggregate	58.9	58.9	58.9	58.9	58.9	0.00595	0.00595	0.00595	0.00595	0.00595
Miscellaneous/Other	672.2	672.2	672.2	672.2	672.2	0.12010	0.12010	0.12010	0.12010	0.12010

TABLE 4
SUMMARY OF CCP USAGE AND AVOIDED GHG EMISSIONS, 2000-2003

CCP End-use Market	Tons CCP Usage				Tons CO₂ Avoided			
	<u>2000</u>	<u>2001</u>	<u>2002</u>	<u>2003</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>	<u>2003</u>
Concrete/Concrete Products/Grout	11,357,204	13,628,275	13,090,433	12,679,134	9,879,639	11,537,389	11,737,305	11,443,871
Cement/Raw Feed for Clinker	1,307,724	1,226,678	2,809,977	3,956,973	0	0	0	0
Flowable Fill	759,085	811,142	456,032	166,129	778,921	832,339	467,949	170,470
Structural Fills/Embankments	4,545,144	4,574,749	6,686,630	8,187,469	25,701	25,869	37,811	46,298
Road Base/Sub-base/Pavement	2,137,850	1,675,785	2,247,131	1,661,388	12,729	9,977	13,379	9,892
Soil Modification/Stabilization	139,803	850,548	1,003,254	773,076	58,469	355,719	419,585	323,319
Mineral Filler in Asphalt	234,482	128,448	240,739	84,010	0	0	0	0
Snow and Ice Control	892,990	871,707	778,712	788,184	17,348	16,935	15,128	15,312
Blasting Grit/Roofing Granules	2,245,560	1,530,028	1,640,125	1,497,744	43,625	29,724	31,863	29,097
Mining Applications	1,700,949	1,078,264	3,841,080	2,330,032	101,047	64,056	228,184	138,418
Wallboard	3,328,651	6,224,872	7,247,856	7,780,906	90,505	169,252	197,066	211,560
Waste Stabilization/Solidification	2,043,095	1,555,595	3,467,327	3,999,623	1,048,243	798,123	1,778,968	2,052,071
Agriculture	94,649	157,199	84,573	50,487	182	414	67	152
Aggregate	N/A	N/A	688,973	687,839	N/A	N/A	4,102	4,095
Miscellaneous/Other	<u>1,373,926</u>	<u>2,806,031</u>	<u>1,240,415</u>	<u>1,741,411</u>	<u>165,005</u>	<u>336,998</u>	<u>148,971</u>	<u>209,139</u>
Total Use	32,161,112	37,119,321	45,523,256	46,384,405	12,221,413	14,176,794	15,080,377	14,653,694

APPENDIX A, TABLE A-1

2000 COAL COMBUSTION PRODUCT (CCP) PRODUCTION AND USE

<u>Usage, by Type of CCP (short tons)</u>					
<u>CCP End-use Market</u>	<u>Fly Ash</u>	<u>Bottom Ash</u>	<u>Boiler Slag</u>	<u>FGD Material</u>	<u>2000 Total CCP Usage</u>
Cement, Concrete, & Grout	10,586,168	419,832	276	350,928	11,357,204
Raw Feed for Cement Clinker	1,133,911	173,813	0	0	1,307,724
Flowable Fill	696,675	10,958	18,000	33,452	759,085
Structural Fills	2,611,054	1,351,390	35,683	547,017	4,545,144
Road Base/Subbase	1,207,750	836,568	13	93,519	2,137,850
Soil Modification	111,896	27,907	0	0	139,803
Mineral Filler	119,011	102,063	12,424	984	234,482
Snow and Ice control	3,076	831,708	58,206	0	892,990
Blasting Grit & Roofing Granules	0	146,983	2,098,577	0	2,245,560
Mining Applications	1,151,536	366,584	0	182,829	1,700,949
Wallboard	0	0	0	3,328,651	3,328,651
Waste Stabilization & Solidification	1,986,277	35,787	0	21,031	2,043,095
Agriculture	13,979	4,748	0	75,922	94,649
Miscellaneous & Other	<u>455,576</u>	<u>629,567</u>	<u>98,389</u>	<u>190,394</u>	<u>1,373,926</u>
Total Use	20,076,909	4,937,908	2,321,568	4,824,727	32,161,112

Source: American Coal Ash Association, *2000 Coal Combustion Product (CCP) Production and Use*.

APPENDIX A, TABLE A-2

2001 COAL COMBUSTION PRODUCT (CCP) PRODUCTION AND USE

<u>CCP End-use Market</u>	<u>Usage, by Type of CCP (short tons)</u>				<u>2001 Total CCP Usage</u>
	<u>Fly Ash</u>	<u>Bottom Ash</u>	<u>Boiler Slag</u>	<u>FGD Material</u>	
Cement, Concrete, & Grout	12,360,242	779,522	0	488,511	13,628,275
Raw Feed for Cement Clinker	1,033,384	162,489	0	30,805	1,226,678
Flowable Fill	803,703	7,439	0	0	811,142
Structural Fills	3,209,508	1,160,262	15,018	189,961	4,574,749
Road Base/Subbase	1,026,821	609,861	0	39,103	1,675,785
Soil Modification	736,986	113,562	0	0	850,548
Mineral Filler	106,539	8,183	12,424	1,302	128,448
Snow and Ice control	0	853,423	18,284	0	871,707
Blasting Grit & Roofing Granules	0	40,089	1,489,939	0	1,530,028
Mining Applications	819,588	118,446	0	140,230	1,078,264
Wallboard	0	0	0	6,224,872	6,224,872
Waste Stabilization & Solidification	1,439,407	68,930	0	47,258	1,555,595
Agriculture	20,506	22,109	0	114,584	157,199
Miscellaneous & Other	<u>448,271</u>	<u>1,768,083</u>	<u>282,808</u>	<u>306,869</u>	<u>2,806,031</u>
Total Use	22,004,955	5,712,398	1,818,473	7,583,495	37,119,321

Source: American Coal Ash Association, *2001 Coal Combustion Product (CCP) Production and Use*, http://www.acaa-usa.org/PDF/2001_rev_svy_11-02.pdf.

APPENDIX A, TABLE A-3

2002 COAL COMBUSTION PRODUCT (CCP) PRODUCTION AND USE

Usage, by Type of CCP (short tons)						
<u>CCP End-use Market</u>	<u>Fly Ash</u>	<u>Bottom Ash</u>	<u>Boiler Slag</u>	<u>FGD Material</u>	<u>FBC Ash</u>	<u>2002 Total CCP Usage</u>
Concrete/Concrete Products/Grout	12,579,136	406,255	9,000	96,042	0	13,090,433
Cement/Raw Feed for Clinker	1,917,690	585,480	0	306,807	0	2,809,977
Flowable Fill	455,018	0	0	1,014	0	456,032
Structural Fills/Embankments	4,200,982	2,046,545	12,103	427,000	0	6,686,630
Road Base/Sub-base/Pavement	767,182	1,472,291	4,484	3,174	0	2,247,131
Soil Modification/Stabilization	904,745	98,509	0	0	0	1,003,254
Mineral Filler in Asphalt	103,173	96,218	38,496	2,852	0	240,739
Snow and Ice Control	2,645	767,455	8,612	0	0	778,712
Blasting Grit/Roofing Granules	61,964	137,455	1,440,706	0	0	1,640,125
Mining Applications	1,888,855	802,582	0	389,643	760,000	3,841,080
Wallboard	0	0	0	7,247,856	0	7,247,856
Waste Stabilization/Solidification	3,187,773	19,091	0	67,053	193,410	3,467,327
Agriculture	0	6,873	0	77,700	0	84,573
Aggregate	0	678,109	3,200	7,664	0	688,973
Miscellaneous/Other	<u>559,718</u>	<u>572,727</u>	<u>33,371</u>	74,599	<u>0</u>	<u>1,240,415</u>
Total Use	26,628,881	7,689,589	1,549,972	8,701,404	953,410	45,523,256

Source: American Coal Ash Association, *2002 Coal Combustion Product (CCP) Production and Use Survey*, [http://www.acaa-usa.org/PDF/acaa_2002_ccp_svy\(11-25-03\).pdf](http://www.acaa-usa.org/PDF/acaa_2002_ccp_svy(11-25-03).pdf).

APPENDIX A, TABLE A-4

2003 COAL COMBUSTION PRODUCT (CCP) PRODUCTION AND USE

Usage, by Type of CCP (short tons)

CCP End-use Market	Fly Ash	Bottom Ash	Boiler Slag	FGD Material	FBC Ash	2003 Total CCP Usage
Concrete/Concrete Products/Grout	12,265,169	298,181	15,907	99,877	0	12,679,134
Cement/Raw Feed for Clinker	3,024,930	493,765	15,766	422,512	0	3,956,973
Flowable Fill	136,618	20,327	0	9,184	0	166,129
Structural Fills/Embankments	5,496,948	2,443,206	11,074	236,241	0	8,187,469
Road Base/Sub-base/Pavement	493,487	1,138,101	29,800	0	0	1,661,388
Soil Modification/Stabilization	515,552	67,998	0	818	188,708	773,076
Mineral Filler in Asphalt	52,608	0	31,402	0	0	84,010
Snow and Ice Control	1,928	683,556	102,700	0	0	788,184
Blasting Grit/Roofing Granules	0	42,604	1,455,140	0	0	1,497,744
Mining Applications	683,925	1,184,927	59,800	390,331	11,049	2,330,032
Wallboard	0	0	0	7,780,906	0	7,780,906
Waste Stabilization/Solidification	3,919,898	30,508	0	0	49,217	3,999,623
Agriculture	12,140	3,534	0	34,813	0	50,487
Aggregate	137,171	512,769	31,600	6,299	0	687,839
Miscellaneous/Other	<u>396,150</u>	<u>1,327,797</u>	<u>2,815</u>	0	<u>14,649</u>	<u>1,741,411</u>
Total Use	27,136,524	8,247,273	1,756,004	8,980,981	263,623	46,384,405

Source: American Coal Ash Association, *2003 Coal Combustion Product (CCP) Production and Use Survey*, [http://www.acaa-usa.org/PDF/2003_CCP_Survey\(10-1-04\).pdf](http://www.acaa-usa.org/PDF/2003_CCP_Survey(10-1-04).pdf).

APPENDIX B, TABLE B-1: CEMENT

A. Fuel Consumption per Equivalent Metric Ton and CO₂ emissions in 2000

Type of Fuel	Unit of Measure	1000 Btu per equiv. metric ton	est. lbs. CO ₂ per 1000 units	lbs. CO ₂ per equiv. metric ton	lbs. CO ₂ per equiv. short ton
Gasoline	1000 Btu	4.6	156.43	0.7	0.7
Middle Distillates	1000 Btu	39.4	161.39	6.4	5.8
Residual Oil	1000 Btu	3.9	173.91	0.7	0.6
LPG	1000 Btu	0.3	139.04	0.0	0.0
Natural Gas	1000 Btu	261.6	117.08	30.6	27.8
Coal	1000 Btu	2,984.1	209.00	623.7	565.8
Petroleum Coke	1000 Btu	760.7	225.13	171.3	155.4
Waste Fuel	1000 Btu	402.5	189.54	76.3	69.2
Electricity	1000 Btu	524.6	405.22	212.6	192.8
Totals		4,981.7	2,204.60	1,122.2	1,018.1

Sources: 1000 Btu Portland Cement Association, *U.S. Industry Fact Sheet, 2002 Edition*, Table 22. Quantities for "Electricity" were originally reported to PCA as per equivalent metric ton: kWh consumed, and were converted by PCA into Btu using 3,412 Btu/kWh.

lbs. CO₂ per U.S. Department of Energy, Energy Information Administration, *Fuel and Energy Source Codes and Emission Coefficients*.

equivalent metric ton: <http://www.eia.doe.gov/oiaf/1605/factors.html>. (Also available as App. B to the Long Form Instructions for the 1605(b) Voluntary Reporting of Greenhouse Gases.) Value for coal is midpoint of bituminous and subbituminous values. Values for "Waste Fuel" based on tire-derived fuel.

Electricity value based on the average lb. CO₂/MWh for all electricity sold in the U.S. in 2000. Using DOE/EIA Annual Energy Review 2001, Table 8.1 (3,605 billion kWh of end-use in 2000) and DOE/EIA Emissions of Greenhouse Gases in the United States 2001, Table 10 (616.6 MMTCE from fuels consumed for electric power in 2000), there was an average of 1,382.61 lb. CO₂/MWh sold. Electricity has an end-use energy value of 3,412 Btu/kWh, yielding a 2000 average of 405.22 lb. CO₂/MMBtu of electric power consumed.

lbs. CO₂ per Calculated using 2204.6 pounds per metric ton.
equivalent short ton:

B. CO₂ Released by the Industrial Process, 2000

	MM tons shipped	Sources:
Clinker production in 2000 (1000 metric tons)	79,417	U.S. Environmental Protection Agency, <i>Inventory of U.S. Greenhouse Gases Emissions and sinks: 1990-2000</i> , USEPA #430-R-02-003, April 15, 2002, http://www.epa.gov/globalwarming/publications/emissions/us2002/index.html , pp. 3-5 to 3-7. EPA estimates an emissions factor of about 0.507 tons of CO ₂ per ton of clinker produced. Since some of the clinker precursor materials remain in the kiln as cement kiln dust (CKD), there are an estimated 2% additional emissions, raising the effective emissions factor to about 0.517 tons CO ₂ per ton of cement.
2000 CO ₂ emissions (1000 MTCE)	41,066	
ton CO ₂ /ton production	0.517	

C. Total per-ton CO₂ emissions from cement production

CO ₂ emissions from energy consumption	1,018.1	lbs. CO ₂ /ton
CO ₂ emissions from industrial process	1,034.2	lbs. CO ₂ /ton
Total CO₂ emissions	2,052.3	lbs. CO₂/ton

APPENDIX B, TABLE B-2: ALL OTHER NONMETALLIC MINERALS (NAICS 212399)

A. Fuel Consumption and CO₂ emissions

Type of Fuel	1997 Delivered Cost (\$1000)	1997 Quantity Consumed	Unit of Measure	MMBtu per unit	1997 million Btu	est. lbs. CO ₂ /MMBtu	tons CO ₂
Coal	\$ -	0.0	1000 tons	22,433	-	209.00	-
Distillate & light diesel	\$ 6,116	174.1	1000 barrels	5,825	1,014,133	161.39	81,833
Resid & heavy diesel	\$ 1,199	54.6	1000 barrels	6,287	343,270	173.91	29,848
Gas (natural & mfr)	\$ 10,795	3.6	million cubic feet	1,026	3,694	117.08	216
Gasoline	\$ 1,299	1.1	million gallons	125,071	137,579	156.43	10,760
Other fuels		-- est.	1000 MMBtu	1,000	--	161.39	--
Undistributed fuels	\$ 7,189	1797.3	est. 1000 MMBtu	1,000	1,797,250	161.39	145,025
Electricity	\$ 25,833	417.6	million kWh	3,412	1,424,851	405.22	288,689
Withheld by Fuel Type	\$ 1,312	328.0	est. 1000 MMBtu	1,000	328,000	161.39	26,467
Totals	\$ 53,743				4,720,776	235.71	556,373

Sources: 1997 U.S. Census Bureau, *Fuels and Electric Energy Report*, 1997 Economic Census, Mining Industry Series. Table 3a, Purchased Fuels and Electric Energy. <http://landview.census.gov/mcd/feetable3a.pdf>. Costs for "Withheld by Fuel Type" were based on total dollar expenditures for purchased fuels and electric energy, less the amounts specifically identified by fuel type. MMBtu quantities for "Other Fuels", "Undistributed Fuels", and "Withheld by Fuel Type" were based on reported dollar expenditures; no quantities were presented, and estimates here are made assuming a delivered fuel price of \$4/MMBtu.

MMBtu per unit: U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384(2001), November 2002. Tables A1, A4, A5. <http://tonto.eia.doe.gov/FTP/ROOT/multifuel/038400.pdf>. Btu contents for coal ("other industrial") and natural gas ("sectors other than elec. utilities") based on 2000 data.

lbs. CO₂ per MMBtu: U.S. Department of Energy, Energy Information Administration, *Fuel and Energy Source Codes and Emission Coefficients*. <http://www.eia.doe.gov/oiaf/1605/factors.html>. (Also available as App. B to the Long Form Instructions for the 1605(b) Voluntary Reporting of Greenhouse Gases.) Value for coal is midpoint of bituminous and subbituminous values. Values for "Other Fuels" and "Undistributed Fuels" are assumed, based on petroleum product values for distillate and light diesel.

Electricity value based on the average lb. CO₂/MWh for all electricity sold in the U.S. in 2000. Using DOE/EIA *Annual Energy Review 2001*, Table 8.1 (3,605 billion kWh of end-use in 2000) and DOE/EIA *Emissions of Greenhouse Gases in the United States 2001*, Table 10 (616.6 MMTCE from fuels consumed for electric power in 2000), there was an average of 1,382.61 lb. CO₂/MWh sold. Electricity has an end-use energy value of 3,412 Btu/kWh, yielding a 2000 average of 405.22 lb. CO₂/MMBtu of electric power consumed.

B. 1997 production

	1000 short tons shipped	Value (\$1000)	Sources:
Diatomite, crude & prepared	757.7	\$ 128,891	U.S. Census Bureau, <i>Product Summary</i> , 1997 Economic Census, Mining Industry Series. June 2001. Table 1. For All other nonmetallic minerals, nsk#, and for Miscellaneous nonmetallic minerals, nsk, the \$ value was given but not the quantity shipped; the quantity shown here was estimated using the same \$/ton average value derived for the other ten categories.
Gypsum	7000.0	\$ 66,131	
Talc, soapstone & pyrophyllite	1195.0	\$ 95,630	
Mica	119.2	\$ 9,374	
Native Asphalt & bitumens	494.4	\$ 19,044	
Pumice & pumicite	757.4	\$ 20,314	
Natural abrasives, except sand	61.9	\$ 21,987	
Peat	402.8	\$ 12,850	
Perlite	811.7	\$ 34,844	
Shell, crushed or broken	1870.4	\$ 10,840	
All other nonmetallic minerals, nsk	5545.0	\$ 172,850	
Misc. Nonmetallic minerals, nsk	1447.2	\$ 45,113	
Total, All Other nonmet. Minerals	20462.7	\$ 637,868	

C. Per-Unit Energy Consumption and CO₂ Emissions

MMBtu consumed per ton	0.231 million Btu/ton
CO ₂ emissions per ton	54.4 lbs. CO ₂ /ton

APPENDIX B, TABLE B-3: CLAY, CERAMIC & REFRACTORY MINERALS (NAICS 212325)

A. Fuel Consumption and CO₂ emissions

Type of Fuel	1997 Delivered Cost (\$1000)	1997 Quantity Consumed	Unit of Measure	MMBtu per unit	1997 million Btu	est. lbs. CO ₂ /MMBtu	tons CO ₂
Coal	\$ 6,897	241.3	1000 tons	22,433	5,413,083	209.00	565,667
Distillate & light diesel	\$ 4,696	207.4	1000 barrels	5,825	1,208,105	161.39	97,486
Resid & heavy diesel	\$ 1,333	68.6	1000 barrels	6,287	431,288	173.91	37,502
Gas (natural & mfrgr)	\$ 20,077	7000.0	million cubic feet	1,026	7,182,000	117.08	420,434
Gasoline	\$ 427	0.4	million gallons	125,071	50,029	156.43	3,913
Other fuels	\$ 1,064	266.0	est. 1000 MMBtu	1,000	266,000	161.39	21,464
Undistributed fuels	\$ 4,194	1048.5	est. 1000 MMBtu	1,000	1,048,500	161.39	84,607
Electricity	\$ 23,695	435.0	million kWh	3,412	1,484,220	405.22	300,718
Withheld by Fuel Type	\$ -	0.0	est. 1000 MMBtu	1,000	-	161.39	-
Totals	\$ 62,383				17,083,225	179.33	1,531,790

Sources: 1997 U.S. Census Bureau, *Fuels and Electric Energy Report*, 1997 Economic Census, Mining Industry Series. Table 3a, Purchased Fuels and Electric Energy. <http://landview.census.gov/mcd/feetable3a.pdf>. Costs for "Withheld by Fuel Type" were based on total dollar expenditures for purchased fuels and electric energy, less the amounts specifically identified by fuel type. MMBtu quantities for "Other Fuels", "Undistributed Fuels", and "Withheld by Fuel Type" were based on reported dollar expenditures; no quantities were presented, and estimates here are made assuming a delivered fuel price of \$4/MMBtu.

MMBtu per unit: U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384(2001), November 2002. Tables A1, A4, A5. <http://tonto.eia.doe.gov/FTP/ROOT/multifuel/038400.pdf>. Btu contents for coal ("other industrial") and natural gas ("sectors other than elec. utilities") based on 2000 data.

lbs. CO₂ per MMBtu: U.S. Department of Energy, Energy Information Administration, *Fuel and Energy Source Codes and Emission Coefficients*. <http://www.eia.doe.gov/oiaf/1605/factors.html>. (Also available as App. B to the Long Form Instructions for the 1605(b) Voluntary Reporting of Greenhouse Gases.) Value for coal is midpoint of bituminous and subbituminous values. Values for "Other Fuels" and "Undistributed Fuels" are assumed, based on petroleum product values for distillate and light diesel.

Electricity value based on the average lb. CO₂/MWh for all electricity sold in the U.S. in 2000. Using DOE/EIA *Annual Energy Review 2001*, Table 8.1 (3,605 billion kWh of end-use in 2000) and DOE/EIA *Emissions of Greenhouse Gases in the United States 2001*, Table 10 (616.6 MMTCE from fuels consumed for electric power in 2000), there was an average of 1,382.61 lb. CO₂/MWh sold. Electricity has an end-use energy value of 3,412 Btu/kWh, yielding a 2000 average of 405.22 lb. CO₂/MMBtu of electric power consumed.

B. 1997 production

	1000 metric tons shipped	Value (\$1000)
Bentonite	4106.6	\$ 180,462
Fire clay	318.7	\$ 2,806
Fuller's Earth	1553.5	\$ 225,660
Feldspar	644.3	\$ 37,341
Crude common clay & shale	724.8	\$ 5,084
Prepared common clay & shale	3750.1	\$ 86,874
Other clay, ceramic, etc.	1085.5	\$ 61,370
Other clay, ceramic, nsk#	256.1	\$ 12,602
Total, clay, ceramic, & refractory	12439.6	\$ 612,199

Sources:

U.S. Census Bureau, *Product Summary*, 1997 Economic Census, Mining Industry Series. June 2001. Table 1. For Other clay, ceramic, nsk#, \$ value was given but not the quantity shipped; the quantity shown here was estimated using the same \$/ton average value derived for the other seven categories.

C. Per-Unit Energy Consumption and CO₂ Emissions

MMBtu consumed per ton	1.514 million Btu/ton
CO ₂ emissions per ton	246.3 lbs. CO ₂ /ton

APPENDIX B, TABLE B-4: CONSTRUCTION SAND & GRAVEL MINING (NAICS 212321)

A. Fuel Consumption and CO₂ emissions

Type of Fuel	1997 Delivered Cost (\$1000)	1997 Quantity Consumed	Unit of Measure	MMBtu per unit	1997 million Btu	est. lbs. CO ₂ /MMBtu	tons CO ₂
Coal	\$ -	0.0	1000 tons	22,433	-	209.00	-
Distillate & light diesel	\$ 48,795	1403.8	1000 barrels	5,825	8,177,135	161.39	659,838
Resid & heavy diesel	\$ 9,652	315.1	1000 barrels	6,287	1,981,034	173.91	172,257
Gas (natural & mfg)	\$ 3,759	1400.0	million cubic feet	1,026	1,436,400	117.08	84,087
Gasoline	\$ 6,044	5.7	million gallons	125,071	712,907	156.43	55,758
Other fuels	\$ -	0.0	est. 1000 MMBtu	1,000	-	161.39	-
Undistributed fuels	\$ 96,872	24218.0	est. 1000 MMBtu	1,000	24,218,000	161.39	1,954,223
Electricity	\$ 160,876	2523.6	million kWh	3,412	8,610,523	405.22	1,744,578
Withheld by Fuel Type	\$ 1,142	285.5	est. 1000 MMBtu	1,000	285,500	161.39	23,038
Totals	\$ 327,140				45,135,999	206.96	4,670,741

Sources: 1997 quantity of fuels consumed: U.S. Census Bureau, *Fuels and Electric Energy Report*, 1997 Economic Census, Mining Industry Series. Table 3a, Purchased Fuels and Electric Energy. <http://landview.census.gov/mcd/feetable3a.pdf>. Costs for "Withheld by Fuel Type" were based on total dollar expenditures for purchased fuels and electric energy, less the amounts specifically identified by fuel type. MMBtu quantities for "Other Fuels", "Undistributed Fuels", and "Withheld by Fuel Type" were based on reported dollar expenditures; no quantities were presented, and estimates here are made assuming a delivered fuel price of \$4/MMBtu.

MMBtu per unit: U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384(2001), November 2002. Tables A1, A4, A5. <http://tonto.eia.doe.gov/FTP/ROOT/multifuel/038400.pdf>. Btu contents for coal ("other industrial") and natural gas ("sectors other than elec. utilities") based on 2000 data.

lbs. CO₂ per MMBtu: U.S. Department of Energy, Energy Information Administration, *Fuel and Energy Source Codes and Emission Coefficients*. <http://www.eia.doe.gov/oiaf/1605/factors.html>. (Also available as App. B to the Long Form Instructions for the 1605(b) Voluntary Reporting of Greenhouse Gases.) Value for coal is midpoint of bituminous and subbituminous values. Values for "Other Fuels" and "Undistributed Fuels" are assumed, based on petroleum product values for distillate and light diesel.

Electricity value based on the average lb. CO₂/MWh for all electricity sold in the U.S. in 2000. Using DOE/EIA *Annual Energy Review 2001*, Table 8.1 (3,605 billion kWh of end-use in 2000) and DOE/EIA *Emissions of Greenhouse Gases in the United States 2001*, Table 10 (616.6 MMTCE from fuels consumed for electric power in 2000), there was an average of 1,382.61 lb. CO₂/MWh sold. Electricity has an end-use energy value of 3,412 Btu/kWh, yielding a 2000 average of 405.22 lb. CO₂/MMBtu of electric power consumed.

B. 1997 production

	MM short tons shipped	Value (\$1000)	Sources:
Construction Sand (run of pit or bank)	48.1	\$ 170,767	U.S. Census Bureau, <i>Product Summary</i> , 1997 Economic Census, Mining Industry Series. June 2001. Table 1. For Construction sand & gravel, nsk#, \$ value was given but not the quantity shipped; the quantity shown here was estimated using the same \$/ton average value derived for the other four categories.
Construction Gravel (run of pit or bank)	48.1	\$ 180,112	
Construction Sand (washed or treated)	216.6	\$ 939,537	
Construction Gravel (washed or treated)	196.0	\$ 1,022,542	
Construction Sand & Gravel, (nsk #)	317.2	\$ 1,441,941	
Total, Construction Sand & Gravel	826.0	\$ 3,754,899	

C. Per-Unit Energy Consumption and CO₂ Emissions

MMBtu consumed per ton	0.055	million Btu/ton
CO ₂ emissions per ton	11.3	lbs. CO ₂ /ton

APPENDIX B, TABLE B-5: INDUSTRIAL SAND MINING (NAICS 212322)

A. Fuel Consumption and CO₂ emissions

Type of Fuel	1997 Delivered Cost (\$1000)	1997 Quantity Consumed	Unit of Measure	MMBtu per unit	1997 million Btu	est. lbs. CO ₂ /MMBtu	tons CO ₂
Coal	\$ -	0.0	1000 tons	22,433	-	209.00	-
Distillate & light diesel	\$ 2,797	87.6	1000 barrels	5,825	510,270	161.39	41,175
Resid & heavy diesel	\$ 824	33.3	1000 barrels	6,287	209,357	173.91	18,204
Gas (natural & mfr)	\$ 17,103	6.4	million cubic feet	1,026	6,566	117.08	384
Gasoline	\$ -	0.0	million gallons	125,071	-	156.43	-
Other fuels	\$ 1,235	308.8	est. 1000 MMBtu	1,000	308,750	161.39	24,914
Undistributed fuels	\$ 3,542	885.5	est. 1000 MMBtu	1,000	885,500	161.39	71,454
Electricity	\$ 31,341	565.9	million kWh	3,412	1,930,851	405.22	391,210
Withheld by Fuel Type	\$ 1,063	265.8	est. 1000 MMBtu	1,000	265,750	161.39	21,444
Totals	\$ 57,905				3,851,294	284.24	547,341

Sources: 1997 U.S. Census Bureau, *Fuels and Electric Energy Report*, 1997 Economic Census, Mining Industry Series. Table 3a, Purchased Fuels and Electric Energy.
quantity of <http://landview.census.gov/mcd/feetable3a.pdf>. Costs for "Withheld by Fuel Type" were based on total dollar expenditures for purchased fuels and electric energy, less the
fuels consumed: amounts specifically identified by fuel type. MMBtu quantities for "Other Fuels", "Undistributed Fuels", and "Withheld by Fuel Type" were based on reported dollar expenditures; no quantities were presented, and estimates here are made assuming a delivered fuel price of \$4/MMBtu.

MMBtu per U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384(2001), November 2002. Tables A1, A4, A5.
unit: <http://tonto.eia.doe.gov/FTP/ROOT/multifuel/038400.pdf>. Btu contents for coal ("other industrial") and natural gas ("sectors other than elec. utilities") based on 2000 data.

lbs. CO₂ U.S. Department of Energy, Energy Information Administration, *Fuel and Energy Source Codes and Emission Coefficients*. <http://www.eia.doe.gov/oiaf/1605/factors.html>. (Also
per MMBtu: available as App. B to the Long Form Instructions for the 1605(b) Voluntary Reporting of Greenhouse Gases.) Value for coal is midpoint of bituminous and subbituminous values. Values for "Other Fuels" and "Undistributed Fuels" are assumed, based on petroleum product values for distillate and light diesel.

Electricity value based on the average lb. CO₂/MWh for all electricity sold in the U.S. in 2000. Using DOE/EIA *Annual Energy Review 2001*, Table 8.1 (3,605 billion kWh of end-use in 2000) and DOE/EIA *Emissions of Greenhouse Gases in the United States 2001*, Table 10 (616.6 MMTCE from fuels consumed for electric power in 2000), there was an average of 1,382.61 lb. CO₂/MWh sold. Electricity has an end-use energy value of 3,412 Btu/kWh, yielding a 2000 average of 405.22 lb. CO₂/MMBtu of electric power consumed.

B. 1997 production

	MM short tons shipped	Value (\$1000)	Sources:
Industrial Glass Sand	13.4	\$ 218,913	U.S. Census Bureau, <i>Product Summary</i> , 1997 Economic Census, Mining Industry Series. June 2001. Table 1. For Industrial Sand, nsk, the \$ value was given but not the quantity shipped; the quantity shown here was estimated using the same \$/ton average value derived for the other three categories.
Industrial Molding Sand	6.2	\$ 83,099	
Other Industrial Sand	7.2	\$ 175,288	
Industrial Sand, nsk	1.4	\$ 24,473	
Total, Industrial Sand	28.2	\$ 501,773	

C. Per-Unit Energy Consumption and CO₂ Emissions

MMBtu consumed per ton	0.137 million Btu/ton
CO ₂ emissions per ton	38.9 lbs. CO ₂ /ton

APPENDIX B, TABLE B-6: OTHER CRUSHED & BROKEN STONE (NAICS 212319)

A. Fuel Consumption and CO₂ emissions

Type of Fuel	1997 Delivered Cost (\$1000)	1997 Quantity Consumed	Unit of Measure	MMBtu per unit	1997 million Btu	est. lbs. CO ₂ /MMBtu	tons CO ₂
Coal	\$ -	0.0	1000 tons	22,433	-	209.00	-
Distillate & light diesel	\$ 15,887	468.4	1000 barrels	5,825	2,728,430	161.39	220,165
Resid & heavy diesel	\$ 1,685	60.3	1000 barrels	6,287	379,106	173.91	32,964
Gas (natural & mfrgr)	\$ 5,851	1800.0	million cubic feet	1,026	1,846,800	117.08	108,112
Gasoline	\$ 1,583	1.5	million gallons	125,071	187,607	156.43	14,673
Other fuels	\$ 174	43.5	est. 1000 MMBtu	1,000	43,500	161.39	3,510
Undistributed fuels	\$ 20,770	5192.5	est. 1000 MMBtu	1,000	5,192,500	161.39	418,998
Electricity	\$ 45,288	722.6	million kWh	3,412	2,465,511	405.22	499,537
Withheld by Fuel Type	\$ -	0.0	est. 1000 MMBtu	1,000	-	161.39	-
Totals	\$ 91,238				12,843,454	202.12	1,297,960

Sources: 1997 quantity of fuels consumed: U.S. Census Bureau, *Fuels and Electric Energy Report*, 1997 Economic Census, Mining Industry Series. Table 3a, Purchased Fuels and Electric Energy. <http://landview.census.gov/mcd/feetable3a.pdf>. Costs for "Withheld by Fuel Type" were based on total dollar expenditures for purchased fuels and electric energy, less the amounts specifically identified by fuel type. MMBtu quantities for "Other Fuels", "Undistributed Fuels", and "Withheld by Fuel Type" were based on reported dollar expenditures; no quantities were presented, and estimates here are made assuming a delivered fuel price of \$4/MMBtu.

MMBtu per unit: U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384(2001), November 2002. Tables A1, A4, A5. <http://tonto.eia.doe.gov/FTP/ROOT/multifuel/038400.pdf>. Btu contents for coal ("other industrial") and natural gas ("sectors other than elec. utilities") based on 2000 data.

lbs. CO₂ per MMBtu: U.S. Department of Energy, Energy Information Administration, *Fuel and Energy Source Codes and Emission Coefficients*. <http://www.eia.doe.gov/oiaf/1605/factors.html>. (Also available as App. B to the Long Form Instructions for the 1605(b) Voluntary Reporting of Greenhouse Gases.) Value for coal is midpoint of bituminous and subbituminous values. Values for "Other Fuels" and "Undistributed Fuels" are assumed, based on petroleum product values for distillate and light diesel.

Electricity value based on the average lb. CO₂/MWh for all electricity sold in the U.S. in 2000. Using DOE/EIA *Annual Energy Review 2001*, Table 8.1 (3,605 billion kWh of end-use in 2000) and DOE/EIA *Emissions of Greenhouse Gases in the United States 2001*, Table 10 (616.6 MMTCE from fuels consumed for electric power in 2000), there was an average of 1,382.61 lb. CO₂/MWh sold. Electricity has an end-use energy value of 3,412 Btu/kWh, yielding a 2000 average of 405.22 lb. CO₂/MMBtu of electric power consumed.

B. 1997 production

	MM tons shipped	Value (\$1000)	Sources:
Bit. Limestone & Sandstone	3.2	\$ 18,108	U.S. Census Bureau, <i>Product Summary</i> , 1997 Economic Census, Mining Industry Series. June 2001. Table 1.
Other crushed and broken stone	214.8	\$ 1,289,743	
Total, Other Stone	218.0	\$ 1,307,851	

C. Per-Unit Energy Consumption and CO₂ Emissions

MMBtu consumed per ton	0.059 million Btu/ton
CO ₂ emissions per ton	11.9 lbs. CO ₂ /ton

APPENDIX C, TABLE C-1: CCP USE AND CO₂ AVOIDANCE IN 2000

CCP End-use Market	Tons of CCPs Used					Tons CO ₂ avoided in 2000				
	Fly Ash	Bottom Ash	Boiler Slag	FGD Material	2000 Total CCP Usage	Fly Ash	Bottom Ash	Boiler Slag	FGD Material	2000 Total CCP Usage
Cement, Concrete, & Grout	10,586,168	419,832	276	350,928	11,357,204	9,875,279	2,374	2	1,984	9,879,639
Raw Feed for Cement Clinker	1,133,911	173,813	0	0	1,307,724	0	0	0	0	0
Flowable Fill	696,675	10,958	18,000	33,452	759,085	714,881	11,244	18,470	34,326	778,921
Structural Fills	2,611,054	1,351,390	35,683	547,017	4,545,144	14,765	7,642	202	3,093	25,701
Road Base/Subbase	1,207,750	836,568	13	93,519	2,137,850	7,191	4,981	0	557	12,729
Soil Modification	111,896	27,907	0	0	139,803	46,798	11,671	0	0	58,469
Mineral Filler	119,011	102,063	12,424	984	234,482	0	0	0	0	0
Snow and Ice control	3,076	831,708	58,206	0	892,990	60	16,158	1,131	0	17,348
Blasting Grit & Roofing Granules	0	146,983	2,098,577	0	2,245,560	0	2,855	40,769	0	43,625
Mining Applications	1,151,536	366,584	0	182,829	1,700,949	68,408	21,777	0	10,861	101,047
Wallboard	0	0	0	3,328,651	3,328,651	0	0	0	90,505	90,505
Waste Stabilization & Solidification	1,986,277	35,787	0	21,031	2,043,095	1,019,091	18,361	0	10,790	1,048,243
Agriculture	13,979	4,748	0	75,922	94,649	136	46	0	0	182
Miscellaneous & Other	<u>455,576</u>	<u>629,567</u>	<u>98,389</u>	<u>190,394</u>	<u>1,373,926</u>	<u>54,714</u>	<u>75,609</u>	<u>11,816</u>	<u>22,866</u>	<u>165,005</u>
Total Use	20,076,909	4,937,908	2,321,568	4,824,727	32,161,112	11,801,321	172,719	72,390	174,983	12,221,413

APPENDIX C, TABLE C-2: CCP USE AND CO₂ AVOIDANCE IN 2001

CCP End-use Market	Tons of CCPs Used					Tons CO ₂ avoided in 2001				
	Fly Ash	Bottom Ash	Boiler Slag	FGD Material	2001 Total CCP Usage	Fly Ash	Bottom Ash	Boiler Slag	FGD Material	2001 Total CCP Usage
Cement, Concrete, & Grout	12,360,242	779,522	0	488,511	13,628,275	11,530,219	4,408	0	2,762	11,537,389
Raw Feed for Cement Clinker	1,033,384	162,489	0	30,805	1,226,678	0	0	0	0	0
Flowable Fill	803,703	7,439	0	0	811,142	824,705	7,633	0	0	832,339
Structural Fills	3,209,508	1,160,262	15,018	189,961	4,574,749	18,149	6,561	85	1,074	25,869
Road Base/Subbase	1,026,821	609,861	0	39,103	1,675,785	6,114	3,631	0	233	9,977
Soil Modification	736,986	113,562	0	0	850,548	308,225	47,494	0	0	355,719
Mineral Filler	106,539	8,183	12,424	1,302	128,448	0	0	0	0	0
Snow and Ice control	0	853,423	18,284	0	871,707	0	16,580	355	0	16,935
Blasting Grit & Roofing Granules	0	40,089	1,489,939	0	1,530,028	0	779	28,945	0	29,724
Mining Applications	819,588	118,446	0	140,230	1,078,264	48,689	7,036	0	8,331	64,056
Wallboard	0	0	0	6,224,872	6,224,872	0	0	0	169,252	169,252
Waste Stabilization & Solidification	1,439,407	68,930	0	47,258	1,555,595	738,511	35,366	0	24,246	798,123
Agriculture	20,506	22,109	0	114,584	157,199	199	215	0	0	414
Miscellaneous & Other	<u>448,271</u>	<u>1,768,083</u>	<u>282,808</u>	<u>306,869</u>	<u>2,806,031</u>	<u>53,836</u>	<u>212,342</u>	<u>33,965</u>	<u>36,854</u>	<u>336,998</u>
Total Use	22,004,955	5,712,398	1,818,473	7,583,495	37,119,321	13,528,647	342,045	63,350	242,752	14,176,794

APPENDIX C, TABLE C-3: CCP USE AND CO₂ AVOIDANCE IN 2002

CCP End-use Market	Tons of CCPs Used						Tons CO ₂ avoided in 2002					
	Fly Ash	Bottom Ash	Boiler Slag	FGD Material	FBC Ash	2002 Total CCP Usage	Fly Ash	Bottom Ash	Boiler Slag	FGD Material	FBC Ash	2002 Total CCP Usage
Concrete/Concrete Products/Gro ut	12,579,136	406,255	9,000	96,042	0	13,090,433	11,734,414	2,297	51	543	0	11,737,305
Cement/Raw Feed for Clinker	1,917,690	585,480	0	306,807	0	2,809,977	0	0	0	0	0	0
Flowable Fill	455,018	0	0	1,014	0	456,032	466,909	0	0	1,040	0	467,949
Structural Fills/Embankments	4,200,982	2,046,545	12,103	427,000	0	6,686,630	23,755	11,573	68	2,415	0	37,811
Road Base/Sub-base/Pavement	767,182	1,472,291	4,484	3,174	0	2,247,131	4,568	8,766	27	19	0	13,379
Soil Modification/Stabilization	904,745	98,509	0	0	0	1,003,254	378,386	41,199	0	0	0	419,585
Mineral Filler in Asphalt	103,173	96,218	38,496	2,852	0	240,739	0	0	0	0	0	0
Snow and Ice Control	2,645	767,455	8,612	0	0	778,712	51	14,909	167	0	0	15,128
Blasting Grit/Roofing Granules	61,964	137,455	1,440,706	0	0	1,640,125	1,204	2,670	27,989	0	0	31,863
Mining Applications	1,888,855	802,582	0	389,643	760,000	3,841,080	112,210	47,678	0	23,147	45,149	228,184
Wallboard	0	0	0	7,247,856	0	7,247,856	0	0	0	197,066	0	197,066
Waste Stabilization/Solidification	3,187,773	19,091	0	67,053	193,410	3,467,327	1,635,538	9,795	0	34,403	99,232	1,778,968
Agriculture	0	6,873	0	77,700	0	84,573	0	67	0	0	0	67
Aggregate	0	678,109	3,200	7,664	0	688,973	0	4,037	19	46	0	4,102
Miscellaneous/Other	<u>559,718</u>	<u>572,727</u>	<u>33,371</u>	<u>74,599</u>	<u>0</u>	<u>1,240,415</u>	<u>67,221</u>	<u>68,783</u>	<u>4,008</u>	<u>8,959</u>	<u>0</u>	<u>148,971</u>
Total Use	26,628,881	7,689,589	1,549,972	8,701,404	953,410	45,523,256	14,424,255	211,775	32,329	267,638	144,381	15,080,377

APPENDIX C, TABLE C-4: CCP USE AND CO₂ AVOIDANCE IN 2003

CCP End-use Market	Tons of CCPs Used						Tons CO ₂ avoided in 2003					
	Fly Ash	Bottom Ash	Boiler Slag	FGD Material	FBC Ash	2003 Total CCP Usage	Fly Ash	Bottom Ash	Boiler Slag	FGD Material	FBC Ash	2003 Total CCP Usage
Concrete/Concrete Products/Gro ut	12,265,169	298,181	15,907	99,877	0	12,679,134	11,441,530	1,686	90	565	0	11,443,871
Cement/Raw Feed for Clinker	3,024,930	493,765	15,766	422,512	0	3,956,973	0	0	0	0	0	0
Flowable Fill	136,618	20,327	0	9,184	0	166,129	140,188	20,858	0	9,424	0	170,470
Structural Fills/Embankments	5,496,948	2,443,206	11,074	236,241	0	8,187,469	31,083	13,816	63	1,336	0	46,298
Road Base/Sub-base/Pavement	493,487	1,138,101	29,800	0	0	1,661,388	2,938	6,776	177	0	0	9,892
Soil Modification/Stabilization	515,552	67,998	0	818	188,708	773,076	215,616	28,438	0	342	78,922	323,319
Mineral Filler in Asphalt	52,608	0	31,402	0	0	84,010	0	0	0	0	0	0
Snow and Ice Control	1,928	683,556	102,700	0	0	788,184	37	13,279	1,995	0	0	15,312
Blasting Grit/Roofing Granules	0	42,604	1,455,140	0	0	1,497,744	0	828	28,269	0	0	29,097
Mining Applications	683,925	1,184,927	59,800	390,331	11,049	2,330,032	40,629	70,392	3,552	23,188	656	138,418
Wallboard	0	0	0	7,780,906	0	7,780,906	0	0	0	211,560	0	211,560
Waste Stabilization/Solidification	3,919,898	30,508	0	0	49,217	3,999,623	2,011,167	15,653	0	0	25,252	2,052,071
Agriculture	12,140	3,534	0	34,813	0	50,487	118	34	0	0	0	152
Aggregate	137,171	512,769	31,600	6,299	0	687,839	817	3,053	188	38	0	4,095
Miscellaneous/Other	<u>396,150</u>	<u>1,327,797</u>	<u>2,815</u>	<u>0</u>	<u>14,649</u>	<u>1,741,411</u>	<u>47,577</u>	<u>159,465</u>	<u>338</u>	<u>0</u>	<u>1,759</u>	<u>209,139</u>
Total Use	27,136,524	8,247,273	1,756,004	8,980,981	263,623	46,384,405	13,931,701	334,279	34,673	246,452	106,589	14,653,694

